SNPO-C

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

SNPO-C

WANL-TME-1207

September 1965

MASTER

Westinghouse Astronuclear Laboratory

PLUGGED CORE FLOW TEST REPORT
PHASE I TESTS - SEAL PERTURBATIONS
(Title Unclassified)

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

[redacted]

MASTER

Astronuclear Laboratory

WANL-TME-1207

September 1965

~~GROUP~~
~~Excluded From ...ic Downgrading~~
~~and ...lassi...~~

102

PLUGGED CORE FLOW TEST REPORT
PHASE I TESTS - SEAL PERTURBATIONS
(Title Unclassified)

Prepared by:

L. A. Salvador
E. H. Schulman
Fluid Flow Laboratory

Classification cancelled ~~(or changed to~~
by authority of _______ TIC, date SEP 11 1973
by H. A. C.

Approved By:

E. A. DeZubay, Manager
Fluid Flow Laboratory

~~INFORMATION CATEGORY~~
~~CONFIDENTIAL R. D.~~
~~Authorized Classifier 10-20-65 Date~~

SPECIAL RE-REVIEW FINAL DETERMINATION
Class: U
Reviewers: KAW Class.: U Date: 4-19-82

[redacted]

DISTRIBUTION OF THIS DOCUMENT UNLIMITED

ABSTRACT

The Seal Perturbation Series of experiments performed on the ND 20701 reactor (Plugged Core) conclusively demonstrated the overall stability of the NRX-A1 design configuration within the envelope of conditions explored. These conditions were ambient temperature hydrogen flow at core inlet pressures ranging from 100 to 700 psia, core pressure drops from 0 to 130 psi, and varying degrees of seal perturbation from a normal condition to venting all 16 effective seals. Core and seal pressure data, core isobar plots, and mechanical data are presented for both perturbed and unperturbed operating conditions.

The isobar plots, based on conformal mapping techniques, indicate the possibility of core radial inflow from the seal region along the first 4/5 of the core periphery. Radial outflow along the last 1/5 of the core periphery is indicated. This is inferred from the existence of a high pressure area at the aft end of the core and a "trough" like depression extending from the aft end peripheral corner of the core, as deep as the 13. 5-inch radius, and as high as the 30-inch core station. In addition, core pressure profiles indicated a positive, stable, bundling force throughout the core with minor exceptions at the aft end and core centerline, for both perturbed and unperturbed operating conditions. Mechanical data indicated that all observed stresses were within design limitations.

[redacted]

TABLE OF CONTENTS

[redacted]

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

[redacted]

I. INTRODUCTION

A. Background

Following the KIWI B-4A hot reactor test in which destructive aeromechanical vibrations were observed, a number of investigations were immediately initiated to determine the specific causes of this instability. At WANL, a small scale flow test with an individual element indicated that vibrations could be induced by gas flow around the outside of the element depending on mass flow rate, channel dimensions, and pressure distribution along the element.[1] Numerous analytical studies[2,3,4,5] were undertaken to investigate the causes of the KIWI B-4A vibrations and their significance to NRX-A designs. These studies concluded that a combination of factors would cause core vibration, but the basic problem in the KIWI B-4A design was insufficient inward bundling pressure over the entire length of the core. Thus the elements would tend to act as individual beams fixed at one end and free to move inward and outward under the force of the flows between them.

As a result of the analytical and early experimental studies, several alternative component tests were suggested to investigate, more fully, the relationship of flow rate, pressure, and other parameters to core mechanical stability.[6] The Seven Cluster Model and Plugged Core Model were selected for extensive experimentation. The Seven Cluster Model was to provide a rapid and efficient tool for studying the NRX-A configuration as well as to simulate KIWI B-4A and other geometries. Several test series were completed with the result that no induced vibrations occurred for the simulated support system and core for the NRX-A1 design or for designs modified to incorporate several features of the KIWI B-4A.[7,8,9] In the final series,[10] in which bundling forces on the core periphery were removed by eliminating the core band and all but the uppermost effective seal, flow induced vibrations were observed. The reduced results appeared to substantiate analytical predictions as well as to add credibility to the adequacy of the Seven Cluster Model.

The Plugged Core Test was initially tested in March 1964. The test design was based primarily on the earlier indications that leakage flows between elements rather than the

[redacted]

[redacted]

main propellant flows were the primary contributors to unstable operation. Thus the main coolant channels were plugged to permit only leakage flows to occur. A full series of steady-state and transient tests were conducted. These tests were conducted during March, April, and May 1964, and are fully described in the Phase I Test Report.[11] Experimental measurements of seal pressure distributions; core pressure distributions; leakage flow rates; mechanical stresses and strains in the inner reflector, tie rods, and elements; and movement of plunger pins, support blocks and other components were made for pressure levels from 55 to 575 psia and for core pressure drops up to 126 psi. The experimental results compared favorably with analytical predictions, including pressure and strain distributions and flow rates. In addition, as predicted, no flow induced vibrations were recorded over the entire spectrum of reactor operation with the anticipated NRX-A1 pressure profiles.

B. Test Objectives and Status

Although the steady-state and transient tests conducted under Phase I of the Plugged Core Flow Tests gave no indication of reactor instability, the results provided no guarantee that under operating conditions less favorable than "design" conditions the reactor would exhibit some instability. For example, the tests did not describe what would occur if bundling pressures on the core were reduced because of, say, a series of ineffective seals. The series of Plugged Core Seal Perturbation Tests described herein were designed to explore these areas of operation more conducive to an unstable core.

Specifically, the objective of the Plugged Core Seal Perturbation Tests was to investigate the area of stable core operation in terms of operating pressures, pressure drops, leakage flow rates, and core bundling pressures, the latter being a direct function of the pressure profiles in the lateral support system seal chambers and the relative pressure profiles at corresponding levels in the core.

In order to carry out this objective, the seal pressure profiles were to be controlled external to the reactor and pressure vessel so as to reduce the seal pressure profile toward the

[redacted]

aft plenum pressure, in a manner similar to the KIWI B-4A. Table 1 illustrates the planned tests in block form. The proposed tests are indicated by a "P"; the completed tests by a "C".

The Seal Perturbation Test series was a part of the Phase I Plugged Core Flow Tests originally proposed[12] and as such made use of the same test model, the ND 20701 reactor. The results previously reported in WANL-TME-792 were designated as those tests prerequisite to NRX-A2 operation and were, therefore, published prior to the completion of the perturbation series. This report is, then, a supplement to the previous report and will contain only those descriptions of the model, procedures, instrumentation, and facilities which are essential for an appreciation of the significance of the results. The reader will be referred to WANL-TME-792 for more detailed descriptions.

II. EXPERIMENTAL

A. Test Model

The test model employed in the seal perturbation series of tests was the ND 20701 reactor (or plugged core) housed in a coded, unfired pressure vessel. The complete assembly is shown in Figure 1. The complete core assembly is illustrated in Figures 2, 3 and 4.

The ND 20701 reactor is generally typical, mechanically speaking, of NRX-A designs through NRX-A2 (ND 10201).[13] It consists of a full core subassembly of Oak Ridge Y-12 uncoated, unfueled, graphite elements; an inner reflector fabricated from H4LM graphite and reimpregnated with a silica dispersion after final machining; core support plate; core support ring; dome end seal; nozzle end seal; aluminum barrel; lateral support system of plunger pins, springs, and seal segments; filler strips; core band; interlocking core support blocks; and related hardware.

There are several modifications of the basic NRX-A design in the ND 20701 design for one or more of the following reasons:

(1) To reduce hydrogen flow requirements for the test and thereby to permit testing within the capabilities of the WANHES flow system.

[redacted]

TABLE 1

PLUGGED CORE SEAL PERTURBATIONS TEST PLAN

Core Pressure Drop, psi	Number of Perturbed Seals	--- Core Inlet Pressure, psia ---		
		300	500	700
50	0	P-C	P-C	P
	4	P-C	P-C	P
	8	P-C	P-C	P
	12	P-C	P-C	P
90	0	P-C	P-C	P
	4	P-C	P-C	P
	8	P-C	P-C	P
	12	P-C	P-C	P
130	0	P-C	P-C	P-C
	4	P-C	P-C	P-C
	8	P-C	P-C	P-C
	12	P-C	P-C	P-C
	16	-C	-C	-C

[redacted]

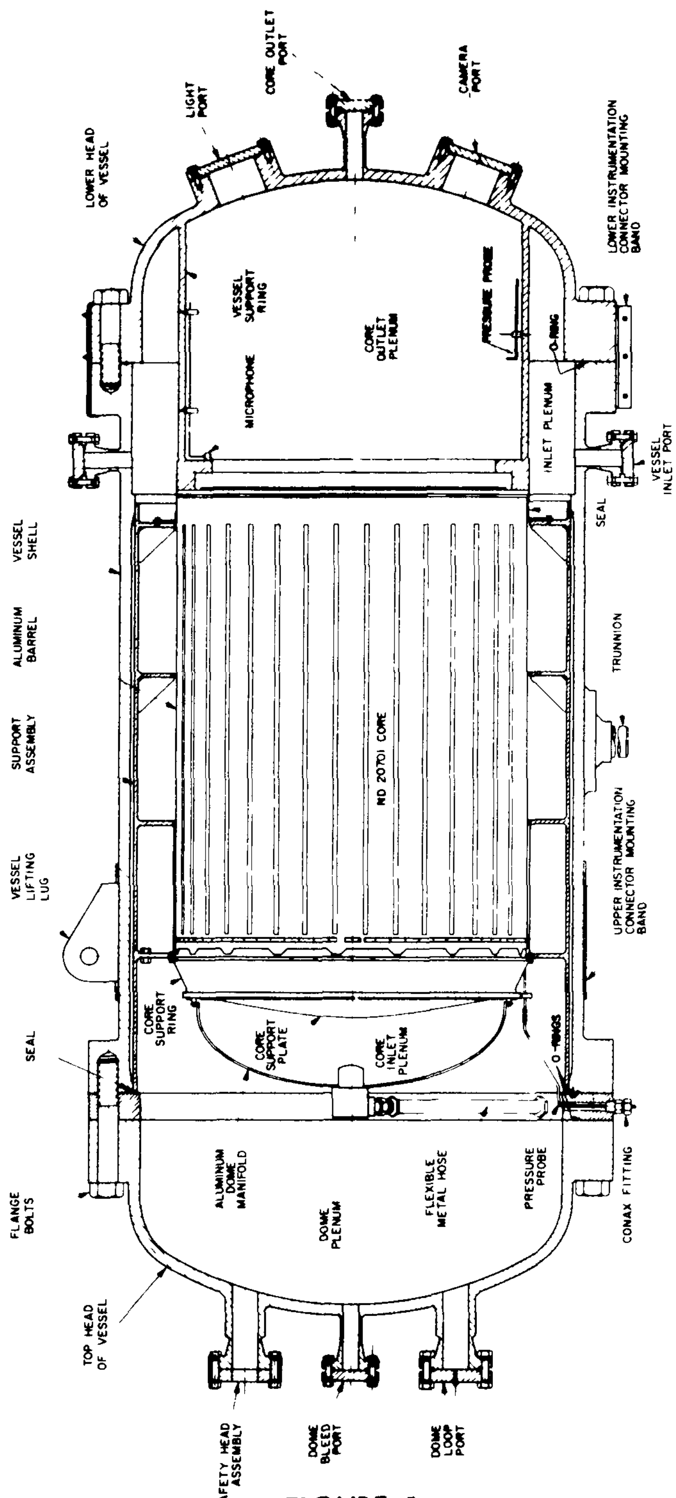


FIGURE 1

PLUGGED CORE FLOW TEST REACTOR AND PRESSURE VESSEL

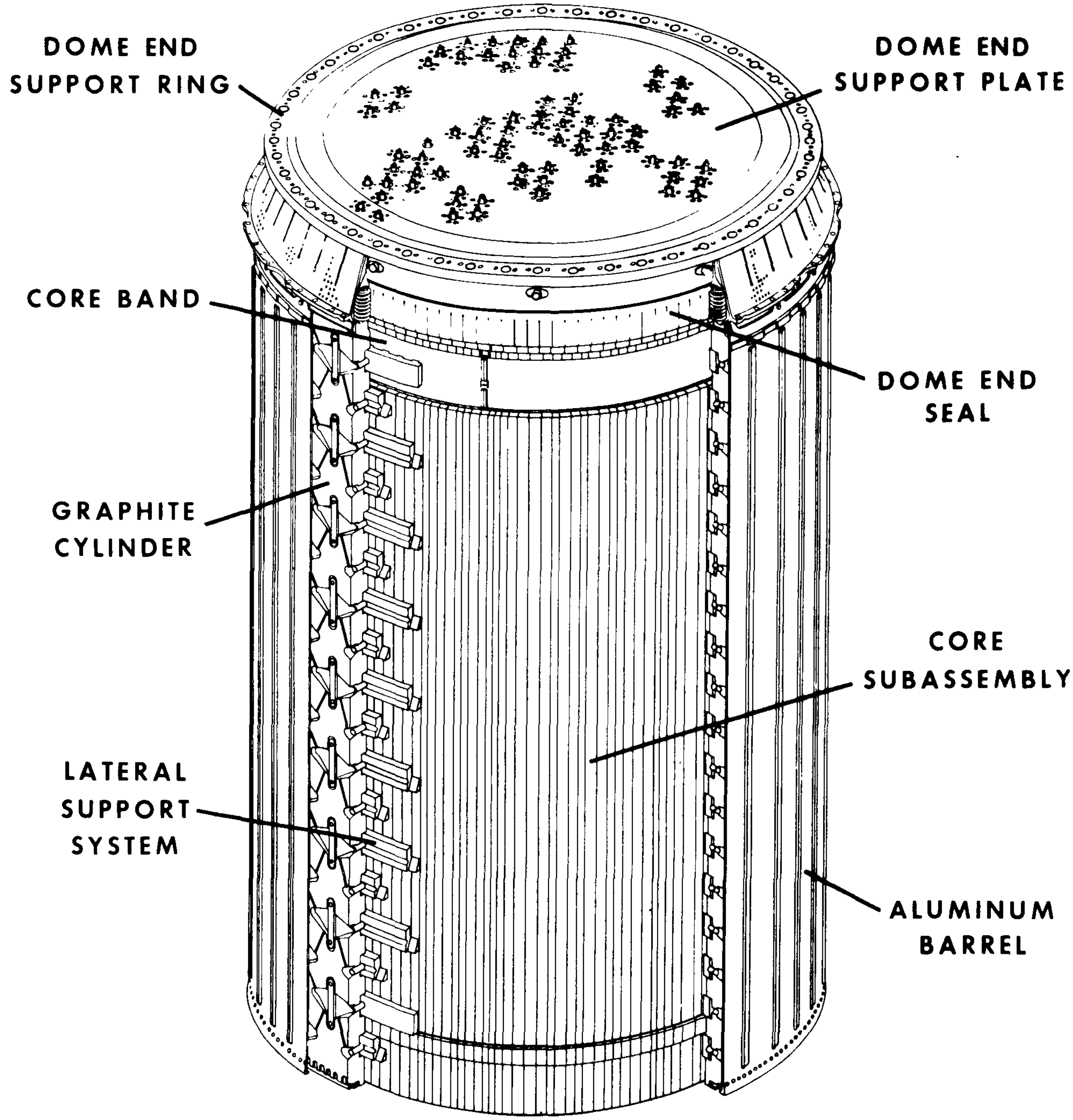


FIGURE 2

CORE SUBASSEMBLY

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

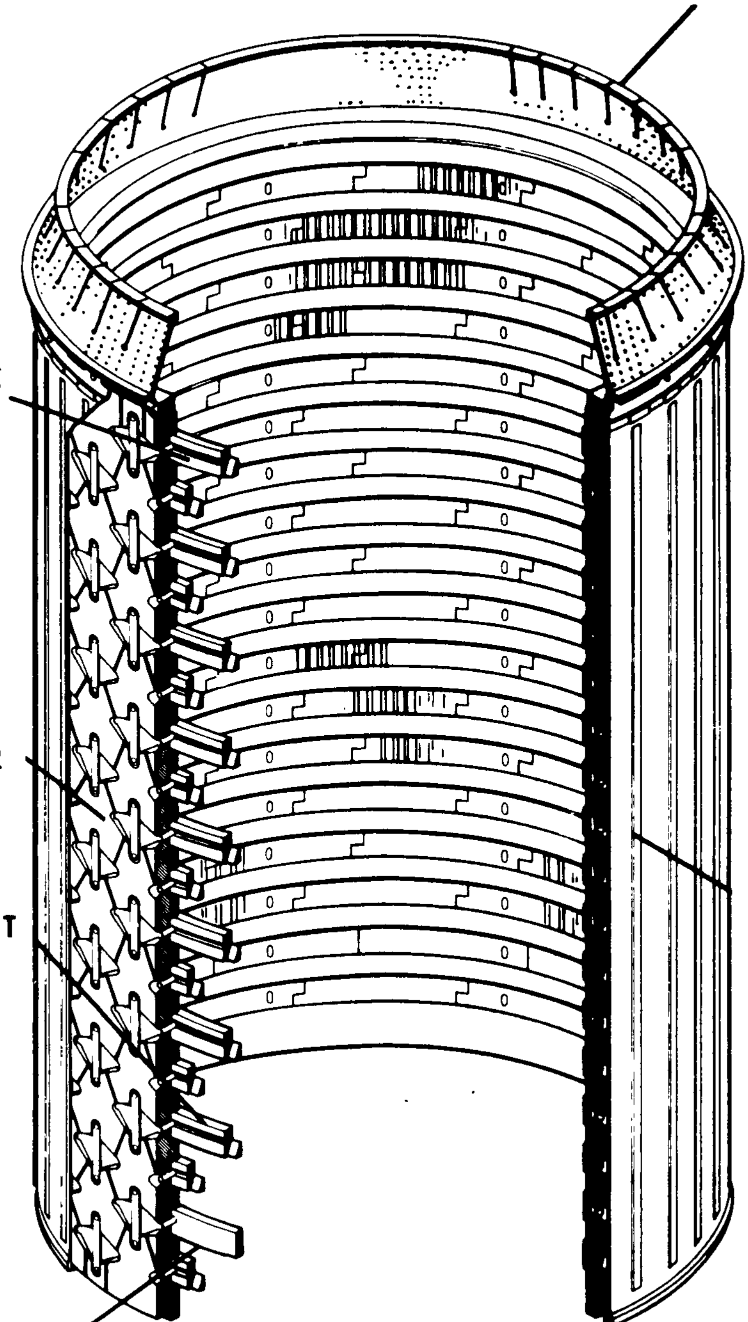


FIGURE 3

INNER REFLECTOR

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

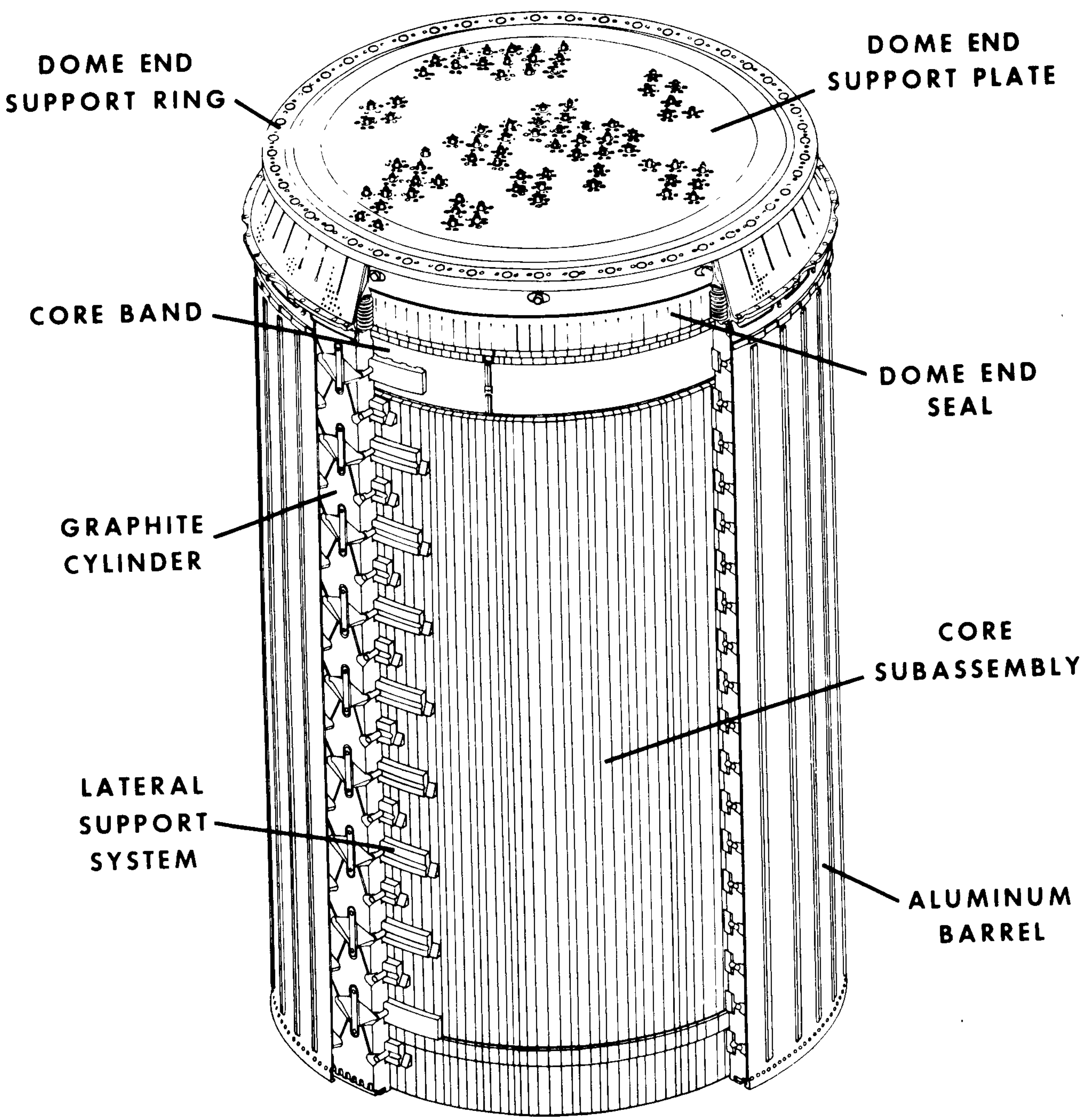


FIGURE 4

CORE ASSEMBLY

(2) To permit a more precise study of leakage flows and their effect on reactor stability and other operating characteristics.

(3) To reduce the cost of the test by eliminating components of the complete reactor which were not essential to the accomplishment of test goals.

The design modification pertinent to the plugged core tests may be summarized by the following:

(1) Substitution of a stainless steel support assembly for the complete outer reflector-control drum assembly.

(2) Plugging of all main propellant flow channels in the elements and inner reflector and around the tie rods.

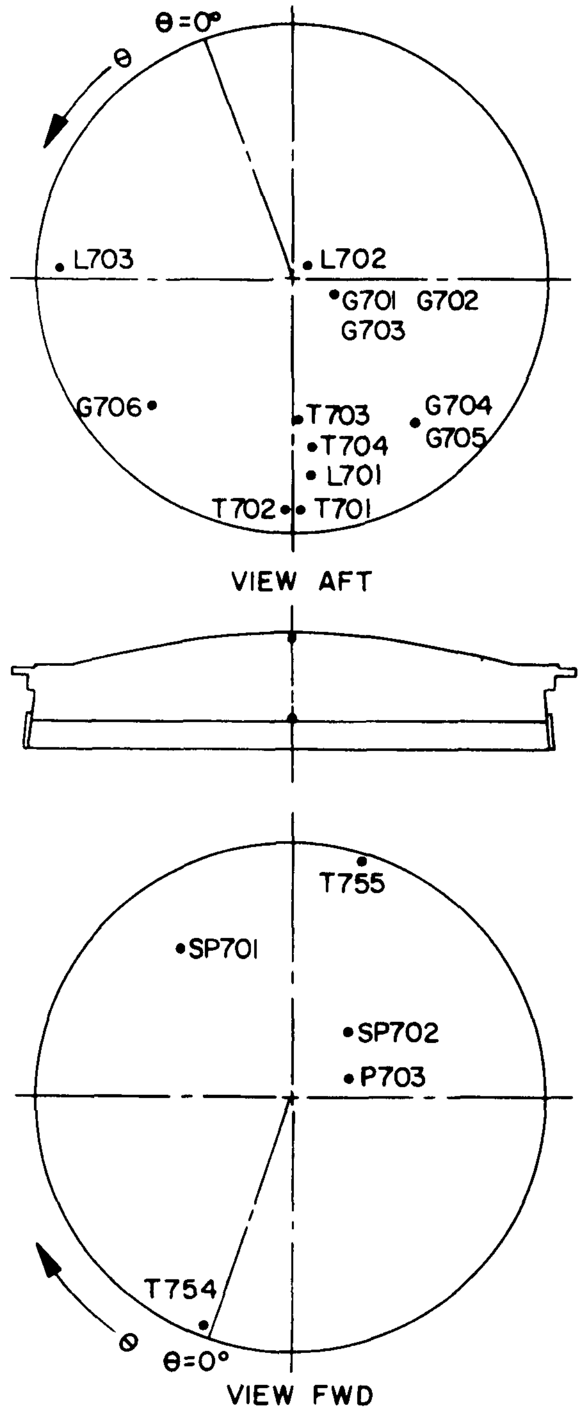
(3) Substitution of an aluminum dome end external flow control loop to simulate the upper aluminum shield and screen.

(4) Installation of pressurizer probes in the inner reflector to permit remote control of seal pressures.

(5) Installation of 37 interelement pressure probes and other instrumentation necessary for the entire test series.

The internal instrumentation in the ND 20701 consists of the sensors necessary to monitor seal pressures; core interstitial pressures; core inlet and outlet pressures; strains in the core support ring, fuel elements, tie rods, and inner reflector; temperatures in the core and support system; relative displacement of the core support plate and core and of the lateral support plunger pin and inner reflector; acceleration of the core support plate and core support blocks; and sound pressure in the core inlet and core outlet plenums. Figures 5 through 9 and Table 2 previously reported,[11] are included here for reference to the specific locations of these sensors.

Of particular interest to the seal perturbation tests are the seal pressurizer probes. These consist of 1/4-inch outside diameter tubes penetrating the pressure vessel through the instrumentation ring and entering an axial coolant channel in the inner reflector. The channel



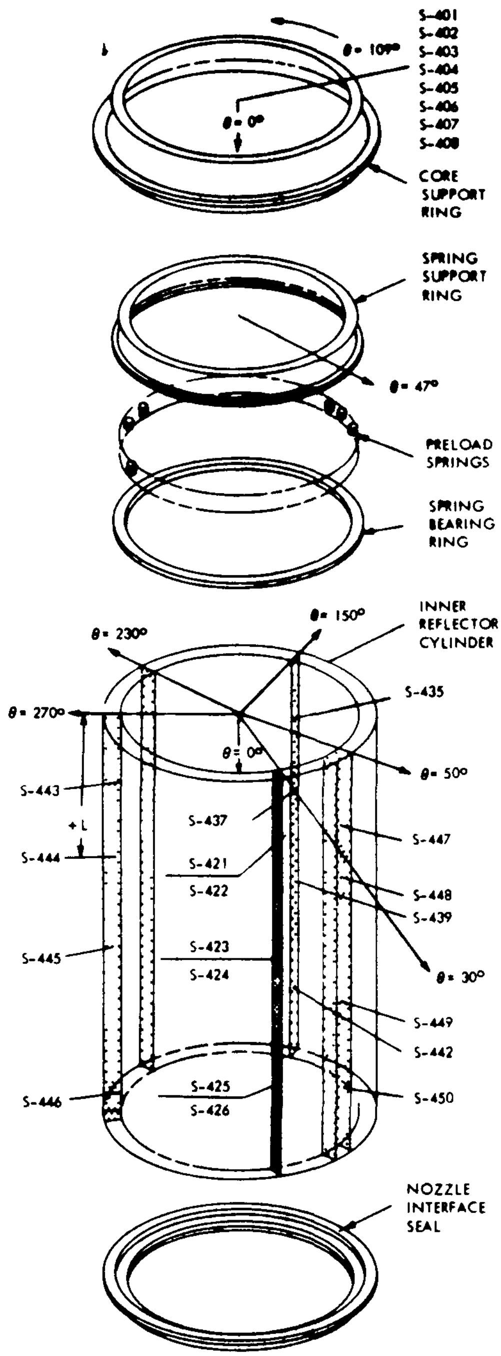
CORE SUPPORT PLATE

GAGE NO.	θ DEGREES	R INCH	SURFACE	TYPE
T-701	162	16.8	Forward	Temperature
T-702	164	16.6	Aft	
T-703	165	10.2	Forward	
T-704	169	10.1	Aft	
T-754	1	17.8	Forward	
T-755	181	17.8	Forward	

GAGE NO.	θ DEGREES	R INCH	SURFACE	TYPE
P-703	228	3.0	Aft	Pressure
SP-701	125	14.1	Aft	Probe Sound Pressure
SP-702	210	4.6	Aft	
L-701	163	15.4	Aft	Linear Displacement between core Support plate and core
L-702	285	.9	Aft	
L-703	70	15.7	Aft	
G-701	209	3.5	Forward	Acceleration
G-702	209	3.5	Forward	
G-703	209	3.5	Forward	
G-704	210	13.9	Forward	
G-705	210	13.9	Forward	
G-706	120	14.0	Forward	

FIGURE 5

CORE SUPPORT PLATE INSTRUMENTATION



STRAIN GAGE LOCATIONS IN INNER REFLECTOR

AND CORE SUPPORT RING

GAGE NO.	θ DEGREES	R INCH	L INCH
S-401	109	18.9	-4.0
S-402	109	19.8	-2.1
S-403	109	20.0	-1.7
S-404	109	18.7	-4.0
S-405	109	19.6	-2.1
S-406	109	19 8	-1.7
S-407	109	20 4	-0 9
S-408	109	20.1	-0.9
S-421	30	19 9	6 9
S-422	30	19.9	
S-423	30	19.9	23.7
S-424	30	19 9	24.2
S-425	30	19 9	40.6
S-426	30	19 9	41.1
S-435	150	Lateral Support Springs	8.6
S-437	150	Lateral Support Springs	19.8
S-439	150	Lateral Support Springs	31.1
S-442	150	Lateral Support Springs	47.9
S-443	270	Lateral Support Springs	8 6
S-444	270	Lateral Support Springs	19.8
S-445	270	Lateral Support Springs	31.1
S-446	270	Lateral Support Springs	42 3
S-447	50	Lateral Support Springs	14.2
S-448	50	Lateral Support Springs	25.4
S-449	50	Lateral Support Springs	36.7
S-450	50	Lateral Support Springs	47 9

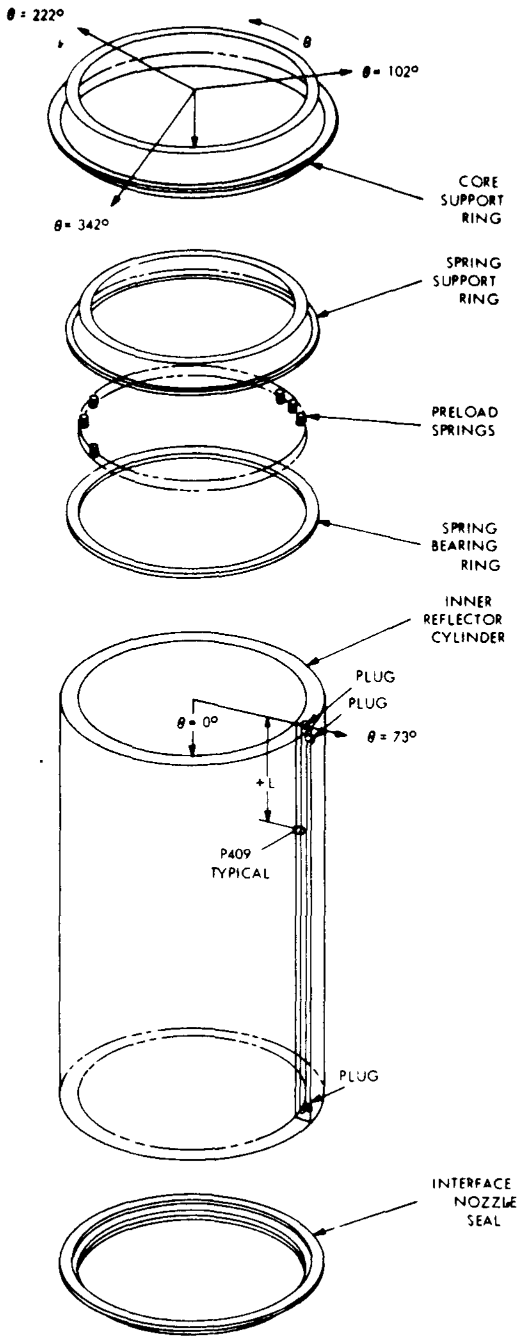
NOTES

R = radius to strain gage

L = location of gage measured from forward edge of inner reflector L s pos tive when measured toward the aft direction

FIGURE 6

STRAIN GAGE INSTRUMENTATION ON INNER REFLECTOR ASSEMBLY



PRESSURE PROBE LOCATIONS IN INNER REFLECTOR

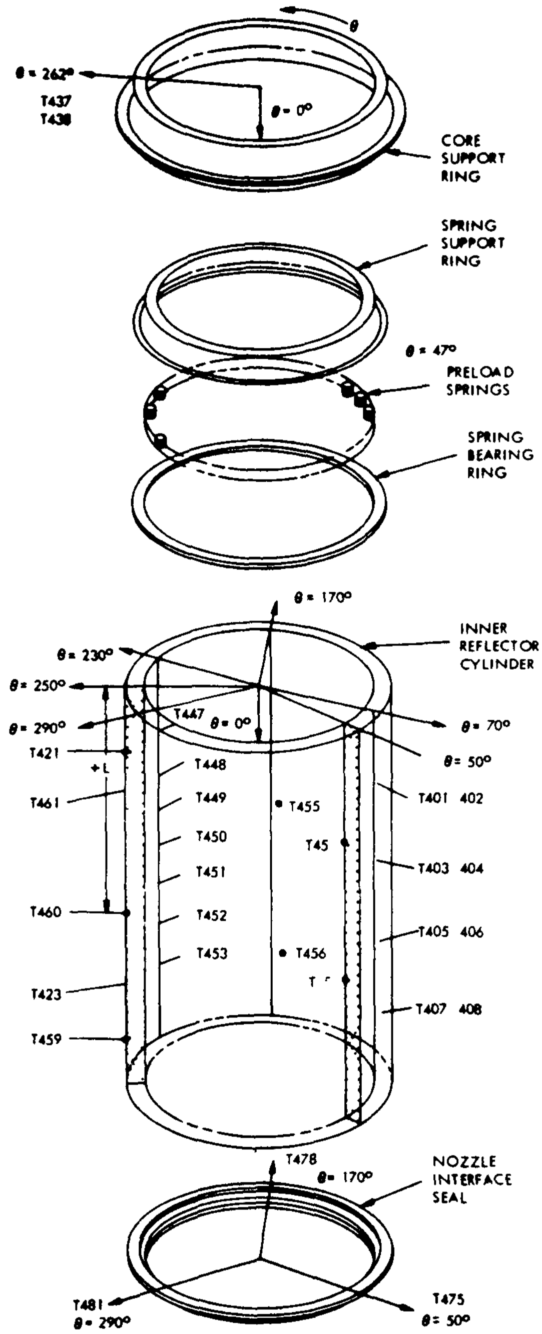
PROBE NO.	θ DEGREES	L INCH
DP-401	163	[illegible].2
DP-402	277	12.8
DP-403	43	18.4
DP-404	173	24.0
DP-405	293	29.6
DP-406	53	35.3
DP-407	157	40.9
DP-408	283	46.5
DP-409	73	9.47
DP-410	97	15.6
DP-411	113	21.2
DP-412	187	26.8
DP-413	217	32.5
DP-414	307	38 1
DP-415	353	43.[illegible]
DP-416	7	6.34
DP-417	67	Thru

NOTES

L = Location of probe measured from forward edge of inner reflector. "L" is positive when measured toward the aft direction.

FIGURE 7

PRESSURE INSTRUMENTATION ON INNER REFLECTOR ASSEMBLY



THERMOCOUPLE LOCATIONS IN INNER REFLECTOR AND CORE SUPPORT RING

GAGE NO	θ DEGREES	R INCH	L INCH
T-401	70	19 9	6 4
T-402	70	19.2	6.6
T-403	70	19 9	17 8
T-404	70	19 2	17 8
T-405	70	19 9	29 1
T-406	70	19 2	29 1
T-407	70	19 9	45 9
T-408	70	19 2	45 9
T-421	250	19 8	8 6
T-423	250	19 8	42 3
T-437	262	19 5	-2 5
T-438	262	20 4	-0 64
T-447	230	seal chamber	10 4
T-448	230	seal chamber	16 0
T-449	230	seal chamber	21 6
T-450	230	seal chamber	27 2
T-451	230	seal chamber	32 9
T-452	230	seal chamber	38 5
T-453	230	seal chamber	44 1
T-454	170	seal chamber	7 2
T-455	170	seal chamber	29.6
T-456	170	seal chamber	40 9
T-457	50	seal chamber	18 4
T 458	50	seal chamber	35 3
T 459	290	seal chamber	46 5
T-460	290	seal chamber	24 0
T-461	290	seal chamber	12 8
T 462	10	seal chamber	4 3
T-475	50	18 7	53 7
T-478	170	18 7	53 7
T-481	290	18 7	53 7

NOTES

R = rad us to nstrument

L = Location of nstrumentat on measured from forward edge of inner reflector The positive direction of L is taken as measuring towards the aft direction

FIGURE 8

THERMOCOUPLE INSTRUMENTATION ON INNER REFLECTOR ASSEMBLY

TABLE 2

SUMMARY OF CORE INSTRUMENTATION

Instrument Designation	Location of Core Instrumentation					Type of Sensor
	Cluster Assembly Element & Hole #	Face of Element	Length from Top of Fuel[1] (inches)	Approximate Radius (inches)	Approximate Azimuth (degrees)	
DP704	0-00-D-13	C	+ 7.16	0	-	Differential Pressure
DP705	1-D4-D-13	C	+ 7.16	7.5	45	Differential Pressure
DP706	3-D4-D-13	C	+ 7.16	7.5	165	Differential Pressure
DP707	5-D4-D-13	C	+ 7.16	7.5	285	Differential Pressure
DP708	3-J7-K-18	D	+ 7.16	17.5	165	Differential Pressure
DP709	5-J7-K-18	D	+ 7.16	17.5	285	Differential Pressure
DP761	1-G7-D-13	C	+ 7.16	13.5	45	Differential Pressure
DP766	1-J6-K- 2	A	+ 7.16	17.5	45	Differential Pressure
DP714	1-D4-D- 7	F	+ 18.40	7.5	45	Differential Pressure
DP720	0-00-D- 7	F	+ 18.40	0	-	Differential Pressure
DP722	3-D4-D- 7	F	+ 18.40	7.5	165	Differential Pressure
DP730	5-D4-D- 7	F	+ 18.40	7.5	285	Differential Pressure
DP742	3-J7-K-16	E	+ 18.40	17.5	165	Differential Pressure
DP762	1-G7-D- 7	F	+ 18.40	13.5	45	Differential Pressure
DP716	1-D4-G-13	C	+ 29.65	7.5	45	Differential Pressure
DP724	3-D4-G-13	C	+ 29.65	7.5	165	Differential Pressure
DP732	5-D4-G-13	C	+ 29.65	7.5	285	Differential Pressure
DP740	1-J9-P-18	D	+ 29.65	17.5	45	Differential Pressure
DP743	0-00-G-13	C	+ 29.65	0	-	Differential Pressure
DP751	5-J9-P-18	D	+ 29.65	17.5	285	Differential Pressure
DP763	1-G7-G- 4	B	+ 29.65	13.5	45	Differential Pressure
DP718	1-D4-G- 7	F	+ 40.90	7.5	45	Differential Pressure
DP726	3-D4-G- 7	F	+ 40.90	7.5	165	Differential Pressure
DP734	5-D4-G- 7	F	+ 40.90	7.5	285	Differential Pressure
DP736	0-00-G- 7	F	+ 40.90	0	-	Differential Pressure
DP738	1-J7-K-18	D	+ 40.90	17.5	45	Differential Pressure
DP741	3-J6-H-18	D	+ 40.90	17.5	165	Differential Pressure
DP746	5-J6-H-18	D	+ 40.90	17.5	285	Differential Pressure
DP764	1-G7-G-13	C	+ 40.90	13.5	45	Differential Pressure
DP767	1-J6-H- 2	A	+ 40.90	17.5	45	Differential Pressure
DP719	1-D4-G- 4	B	+ 46.52	7.5	45	Differential Pressure
DP727	3-D4-G- 4	B	+ 46.52	7.5	165	Differential Pressure
DP735	5-D4-G- 4	B	+ 46.52	7.5	285	Differential Pressure
DP737	1-J7-K-16	E	+ 46.52	17.5	45	Differential Pressure
DP747	0-00-G- 4	B	+ 46.52	0	-	Differential Pressure
DP748	5-J7-K-16	E	+ 46.52	17.5	285	Differential Pressure
DP765	1-G7-G- 7	F	+ 46.52	13.5	45	Differential Pressure
T720	-	Core Inlet Plenum		14.8	0	Thermocouple
T726	-	Core Inlet Plenum		14.8	120	Thermocouple
T730	-	Core Inlet Plenum		14.8	240	Thermocouple
T732	1-E5-B- 7	Core Exit	+ 54. 7	8.5	45	Thermocouple
T735	3-E5-B- 7	Core Exit	- 54. 7	8.5	165	Thermocouple
T739	5-E5-B- 7	Core Exit	+ 54. 7	8.5	285	Thermocouple

TABLE 2 (CONTINUED)

Instrument Designation	Location of Core Instrumentation: Cluster Assembly Element & Hole #	Face of Element	Length from Top of Fuel[1] (inches)	Approximate Radius (inches)	Approximate Azimuth (degrees)	Type of Sensor
T710	3-J9-U-13	C	+ 14.5	17.0	180	Thermocouple
T711	5-J9-U-13	C	+ 42.0	17.5	300	Thermocouple
T712	5-E4-A- 1	A	+ 25.8	8.5	285	Thermocouple
T713	3-J9-R-18	D	+ 25.8	15.5	180	Thermocouple
T714	3-J9-W-18	C	+ 3.2	16.0	180	Thermocouple
T715	3-J9-V- 4	B	+ 50.8	16.0	180	Thermocouple
T716	6-J9-T-18	D	+ 8.6	17.5	0	Thermocouple
T717	2-J9-T-18	D	+ 19.8	17.0	120	Thermocouple
T718	4-J9-T-18	D	+ 47.9	17.0	300	Thermocouple
S709	5-E4-E-17	C	+ 26.5	8.5	285	Strain Gage
S710	5-E4-F- 1	A	+ 26.5	8.5	285	Strain Gage
S712	5-E4-C- 3	F	+ 26.5	8.5	285	Strain Gage
S715	5-E4-C-19	D	+ 26.5	8.5	285	Strain Gage
S726	5-E4-A- 9	E	+ 26.5	8.5	285	Strain Gage
S728	5-E4-F- 2	A	+ 3.9	8.5	285	Strain Gage
S732	5-E4-F-13	C	+ 3.9	8.5	285	Strain Gage
S735	5-E4-C- 7	F	+ 3.9	8.5	285	Strain Gage
S739	5-E4-C-18	D	+ 3.9	8.5	285	Strain Gage
S740	5-E4-A- 3	B	+ 26.5	8.5	285	Strain Gage
S774	5-J7-F- 2	A	+ 3.9	17.0	285	Strain Gage
S775	5-J7-F- 1	A	+ 26.5	17.0	285	Strain Gage
S776	5-J7-F-17	D	+ 3.9	17.0	285	Strain Gage
S777	5-J7-F-13	C	+ 26.5	17.0	285	Strain Gage
S757	2-B1-A	Tie Rod	- 5.0	4.0	45	Strain Gage
S758	2-B1-A	Tie Rod	- 5.0	4.0	45	Strain Gage
S759	2-G1-A	Tie Rod	- 5.0	14.5	45	Strain Gage
S760	2-G1-A	Tie Rod	- 5.0	14.5	45	Strain Gage
S761	4-B1-A	Tie Rod	- 5.0	4.0	180	Strain Gage
S762	4-B1-A	Tie Rod	- 5.0	4.0	180	Strain Gage
S763	3-J9-A	Tie Rod	- 5.0	15.5	180	Strain Gage
S764	3-J9-A	Tie Rod	- 5.0	15.5	180	Strain Gage
S765	5-B2-A	Tie Rod	- 5.0	4.0	285	Strain Gage
S766	5-B2-A	Tie Rod	- 5.0	4.0	285	Strain Gage
S767	5-G7-A	Tie Rod	- 5.0	13.0	285	Strain Gage
S768	5-G7-A	Tie Rod	- 5.0	13.0	285	Strain Gage
G707	6-H5-C-13	C	+ 53.8	14.0	330	Accelerometer
G708	0-00-F-16	E	+ 53.8	0	-	Accelerometer
G709	0-00-B-16	E	+ 53.8	0	-	Accelerometer
G710	4-G2-G- 2	A	+ 53.8	12.0	180	Accelerometer
G711	4-H5-C-13	C	+ 53.8	14.0	210	Accelerometer
G712	6-H3-G- 2	A	+ 53.8	14.0	315	Accelerometer

NOTE: 1. Positive sign indicates that measurement is from top of fuel toward aft end. Negative sign indicates that sensor is located above core (i.e. forward).

Astronuclear Laboratory

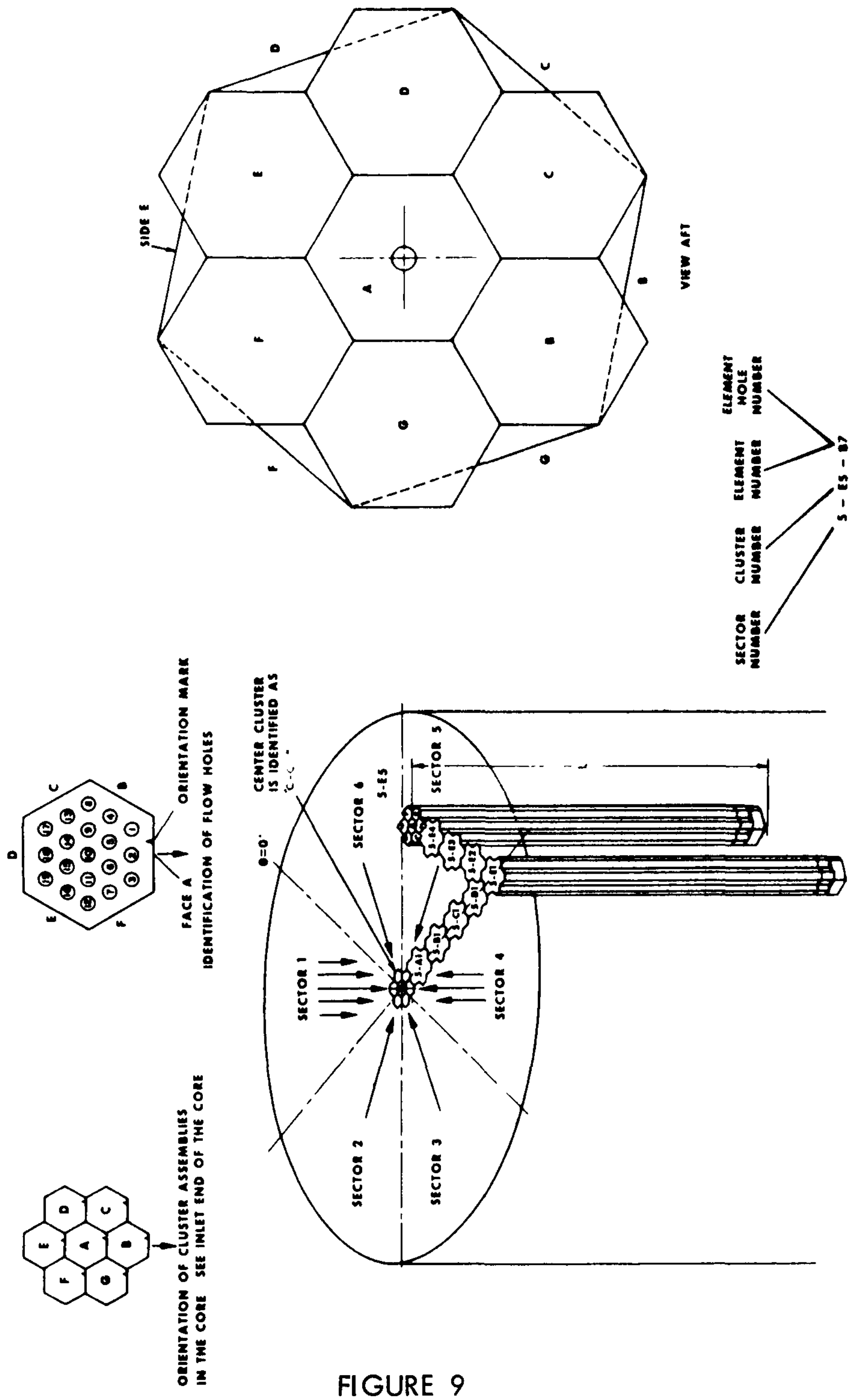


FIGURE 9

CORE IDENTIFICATION CONVENTION FOR NRX-A REACTORS is plugged at the top and bottom and is drilled radially to enter the chamber between seal segments as shown in Figure 10. These probes are located between each effective seal at a point on the inner reflector 180 degrees from the corresponding seal pressure probe in a given seal chamber. The latter probes are used to measure seal pressures, whereas the pressurize probes are used either to admit gas to a seal region or bleed gas from the seal region.

Every sensor used during the seal perturbation series was recorded continuously during the transient and steady-state portions of the test and must, therefore, be considered as a dynamic monitor of reactor stability. However, because of the particular response characteristics, more favorable location, or previous indication of reliability, certain sensors were used as primary indicators of the dynamic behavior of reactor components during the tests. These include:

(1) Core support block accelerometers.
(2) Lateral support spring strain gages.
(3) Fuel element strain gages.
(4) Tie rod strain gages.
(5) High speed photography of the core support blocks.

B. Test Operation

The flow system at WANHES used in the seal perturbation tests was described in the first Plugged Core Flow Test Report and is partially illustrated in Figures 11 and 12. For these tests, the gaseous hydrogen storage sphere (20,000 SCF) and two gaseous hydrogen storage trailers (177,000 SCF) were used in parallel to provide the high pressure gas required. Using the two sources in this manner provided full, undiminished flow at test pressures for a longer duration than could be attained with either source alone. As a result, a greater number of pressure holds could be tested during one test run.

The test sequence consisted of providing controlled pressures at the vessel inlet, core outlet, and seal chambers, while pressure and flow distributions within the core adjusted

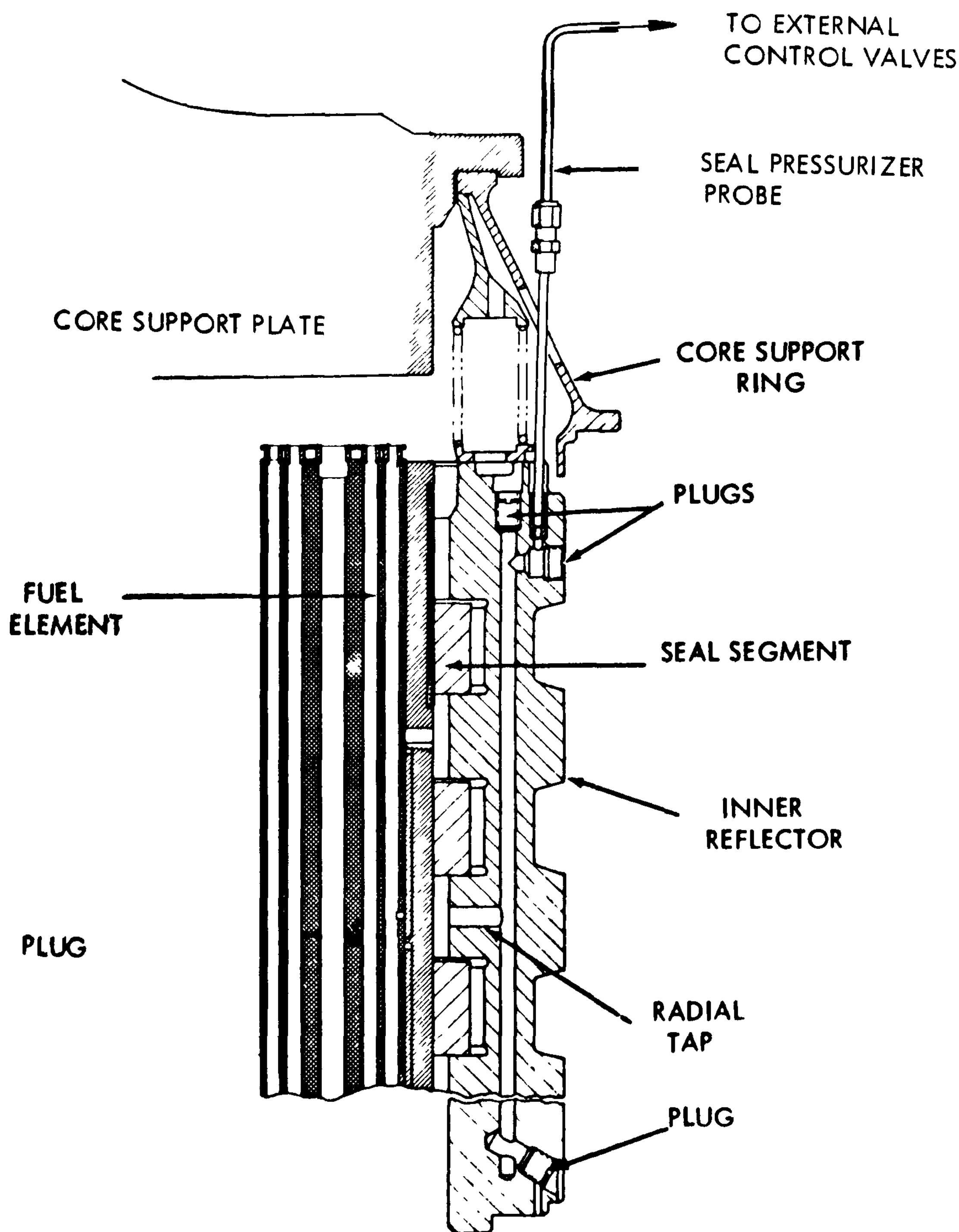


FIGURE 10

PRESSURIZER PROBE INSTALLATIONS IN SEALS

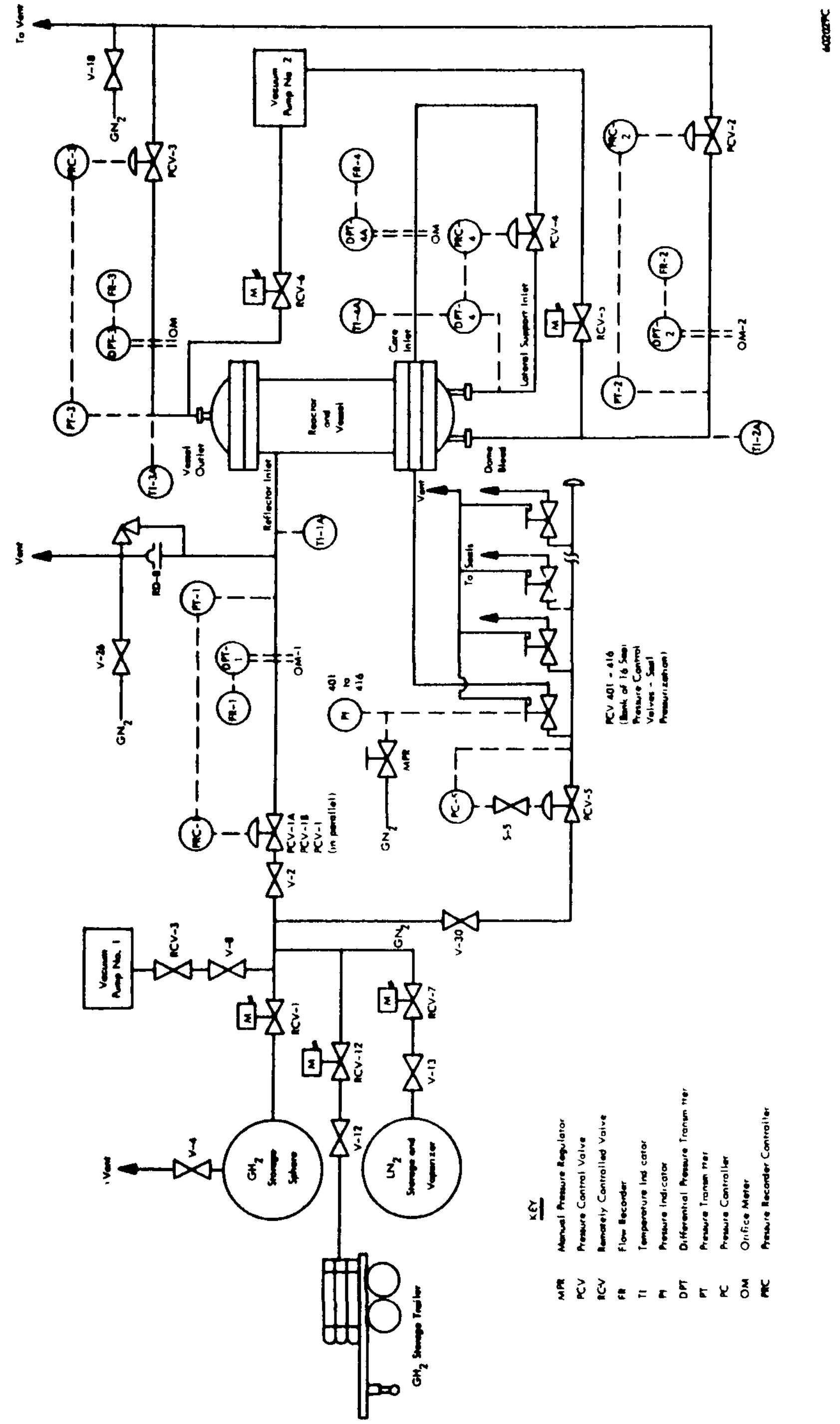


FIGURE 11

PLUGGED CORE FLOW TEST SIMPLIFIED FLOW DIAGRAM

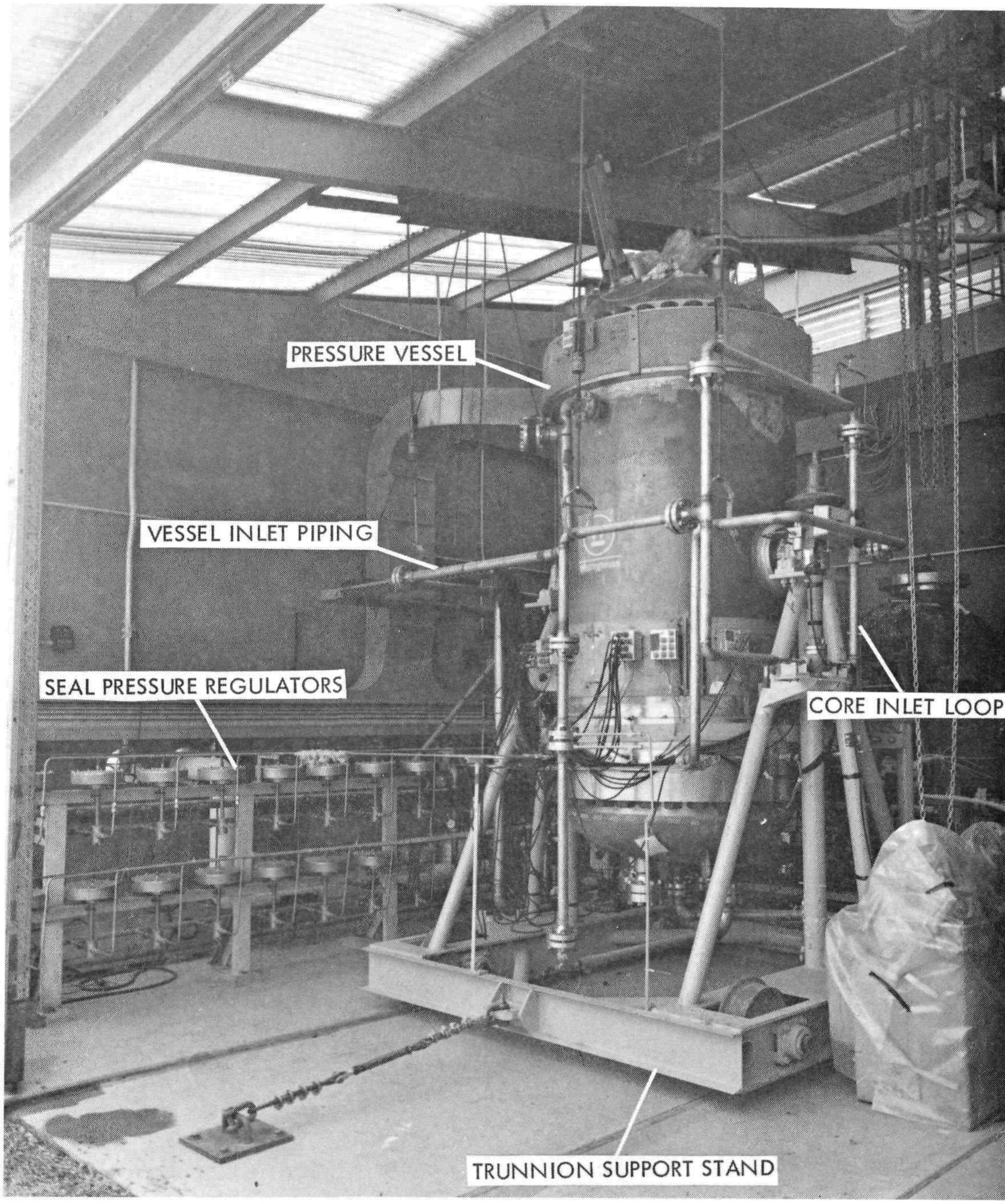


FIGURE 12

PLUGGED CORE FLOW TEST SHOWING PRESSURE VESSEL
AND TRUNNION SUPPORT STAND,
SEAL PRESSURE REGULATORS, AND PROCESS PIPING

to these boundary conditions. Vessel inlet pressure was controlled through valve PCV-1A or PCV-1B from the high pressure supply by way of a primary sensing device and pneumatic transmitter PT-1 monitoring pressure in the vessel inlet plenum. Similarly, pressures in the core inlet and outlet plenums were monitored by PT-2 and PT-3 and controlled by valves PCV-2 and PCV-3. Orifice meters 0-1, 2, and 3 were used to measure flow rates in these streams.

The control of seal pressures was accomplished in a somewhat different manner. High pressure hydrogen was supplied to the upstream side of valve PCV-5, and this valve controlled the downstream pressure to a value slightly higher than core inlet pressure. The seal pressure regulators PCV-401 through PCV-416 were connected to the sixteen seal pressurizer probes and were used to control the pressure in each seal chamber. This was accomplished by a venting action (bleeding of gas from the chamber) or a pressurizing action (adding gas to the chamber) depending on whether or not the actual seal pressure was above or below the pressure level pre-set on the control valves. This pre-set actuator pressure was controlled remotely from the control room. Figure 13 schematically shows this control mode.

In practice the seal pressure regulators were not used in the pressurizing mode since the net effect of increasing the seal pressures is to increase core bundling and stability. In order to provide a core less stable than the normal model, seal pressures were lowered by employing the regulators in the venting mode. This was done for each test pressure by successively venting groups of four seals starting at the aft end of the core. Thus at a given core inlet pressure and pressure drop a steady-state test was conducted with no venting to provide a normal or control test. Hydrogen flow was then stopped and the reactor held at core outlet pressure while the actuator pressures on the regulators to the last four seals were pre-set. A second steady-state test was then conducted with the four seals vented. This procedure was repeated until all sixteen seals were fully vented.

Procedurally, the tests were conducted according to the following outline:

(1) Complete functional check-out of all systems.

(2) Power turned on.

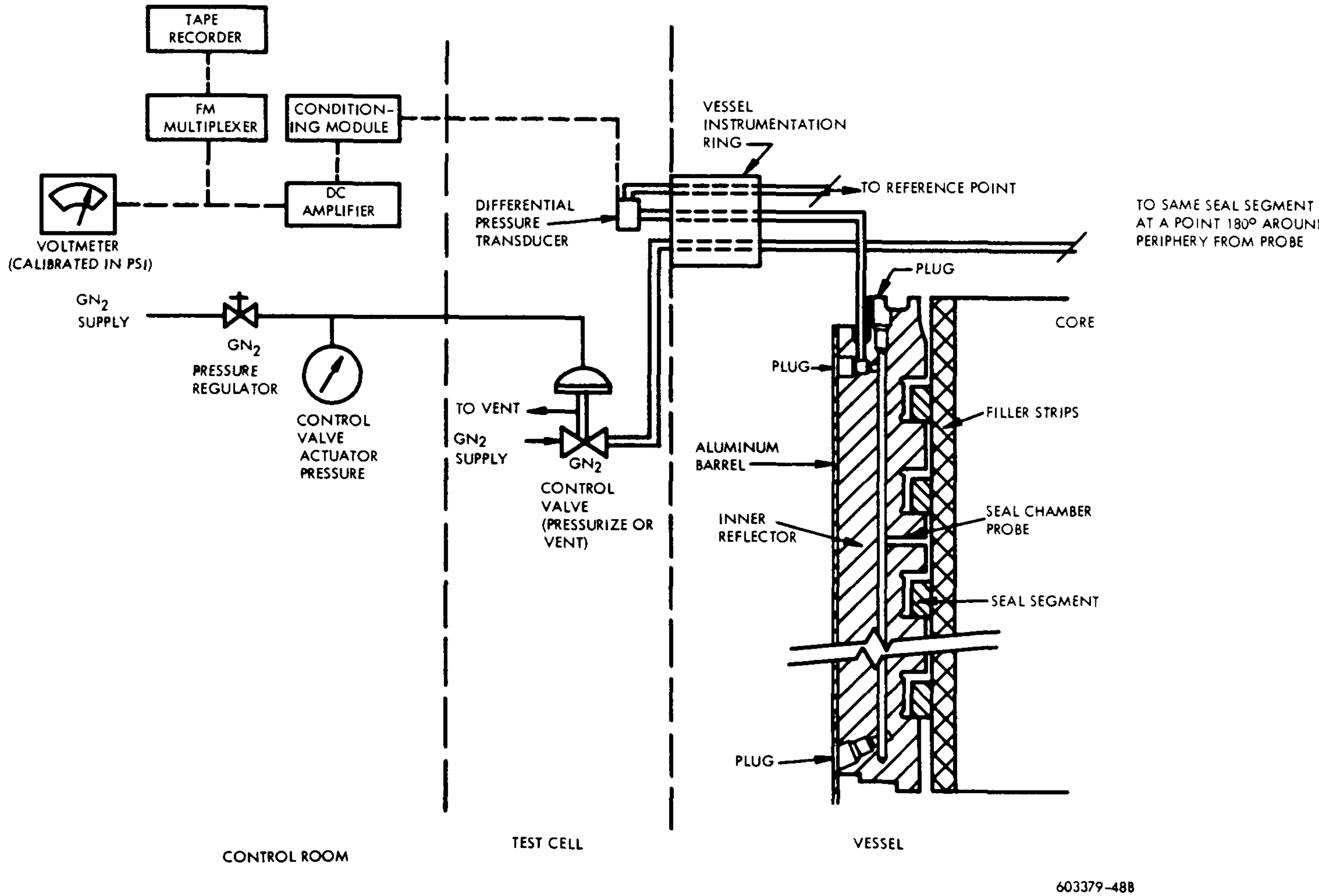


FIGURE 13

SEAL PRESSURE MEASUREMENT AND CONTROL SCHEMATIC

(3) Established purge flow to vent stacks.

(4) Evacuated entire system to 5 mm Hg absolute.

(5) Back-filled system with GN_2 at 30 psig.

(6) Repeated evacuation and back-fill twice.

(7) Connected hydrogen gas supply.

(8) Brought system to atmospheric pressure and recorded calibration of all instruments on tape recorder and oscillograph.

(9) Installed movie camera on test model.

(10) Evacuated test cell and turned warning lights on.

(11) All pressure controls were pre-set.

(12) Seal pressure regulator actuating pressures were pre-set.

(13) Evacuated system to 5 mm Hg absolute.

(14) Back-filled system to atmospheric pressure with gaseous hydrogen.

(15) Ignited flare.

(16) Performed final countdown:

Started time code generator.

Started tape recorders and oscillograph.

Started flow and pressure recorders.

Opened GH_2 supply valve.

Actuated flow control valve PCV-1A or 1B.

Started cameras.

Marked steady-state hold.

(17) Check all systems for proper data acquisition.

(18) Closed flow control valve PCV-1A or 1B.

(19) Pre-set seal regulator actuator pressures to second level.

(20) Ramped operating pressures to second level and marked second hold.

(21) Continued through prescribed series of pressure level holds.

(22) Closed GH_2 supply valve.

(23) Vented system.

(24) Turned off all recording instruments.

(25) Purged system with gaseous nitrogen.

(26) Evacuated system to 5 mm Hg absolute.

(27) Back filled system with nitrogen.

(28) Performed final instrument calibration.

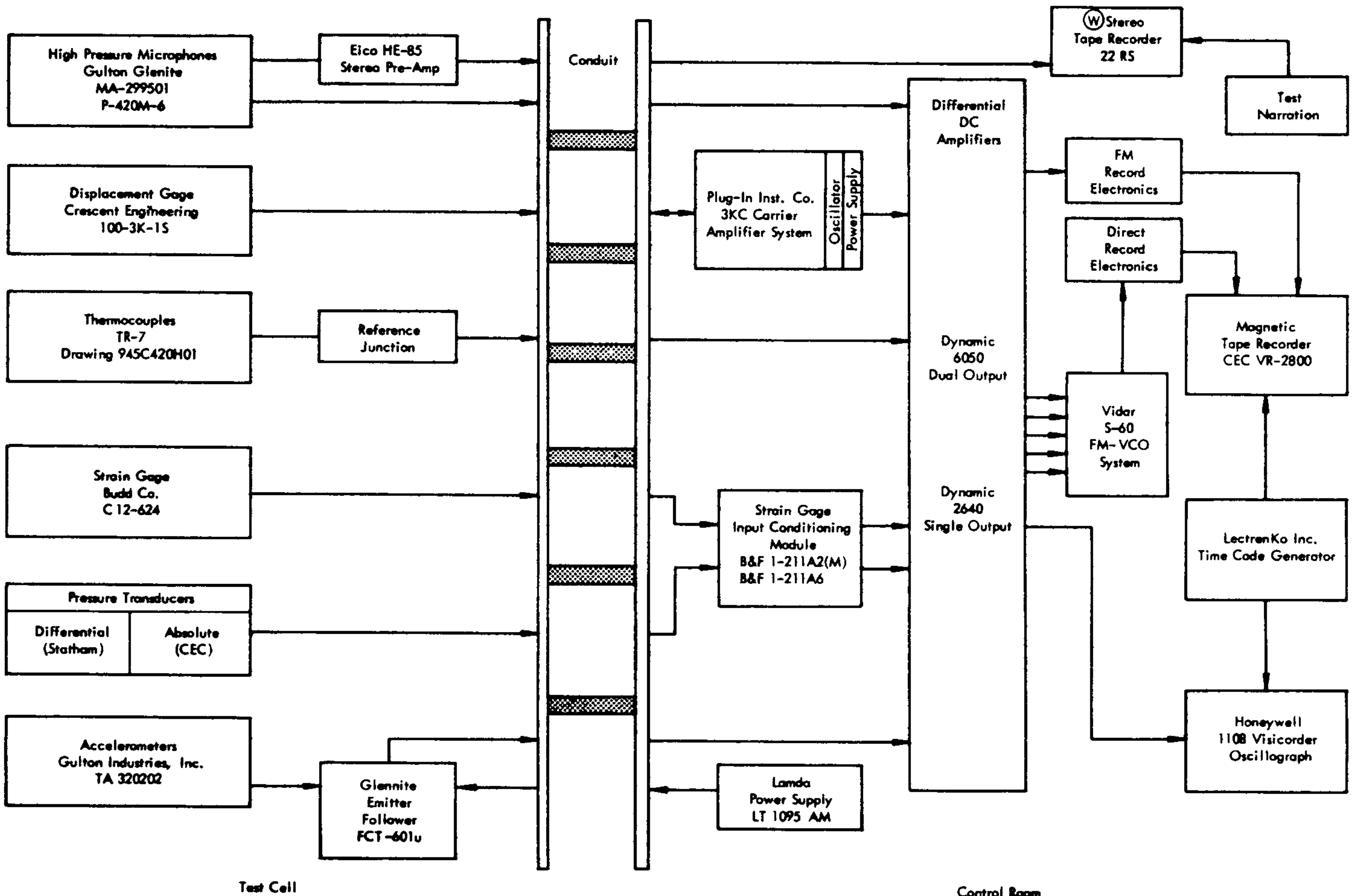
(29) Disconnected hydrogen supply and secured system.

Test data was sensed and transmitted by the internal sensors described in Section III-A above as well as by additional sources outside the pressure vessel. The signals from the internal sensors were handled by the basic 98 channel FM wideband and FM/FM data acquisition system shown in Figures 14 and 15. Many of the primary dynamic sensors such as accelerometers on the support blocks were recorded directly on the recording oscillograph for "quick-look" analysis of the test during and after the test and for indications of gross instabilities warranting a rapid shut-down during the test.

In addition to the internal sensors, there were pneumatic transmitters in the core inlet, core outlet, vessel inlet, and dome loop piping to monitor hydrogen pressures. These were recorded continuously on pressure recorders in the control room. As a back-up to the seal pressure transducers, a bank of precise pressure gages were tied into the seal pressure probes. This data was recorded on film every second during the test by an automatic camera in the test cell. A closed circuit TV system was also employed to view these pressure gages in the control room. Signals from differential pressure transmitters across the orifice meter taps were recorded continuously on pneumatic flow recorders in the control room. Finally, a high speed movie camera operated at a speed of 250 frames per second was used to record the behavior of the aft surface of the core.

C. Test Results

The test series consisted of experiments at nominal core inlet pressures of 300, 500, and 700 psia and nominal core pressure drops of 50, 90, and 130 psi in which increasingly severe



602028C

FIGURE 14

LAYOUT OF WANHES DATA ACQUISITION SYSTEM

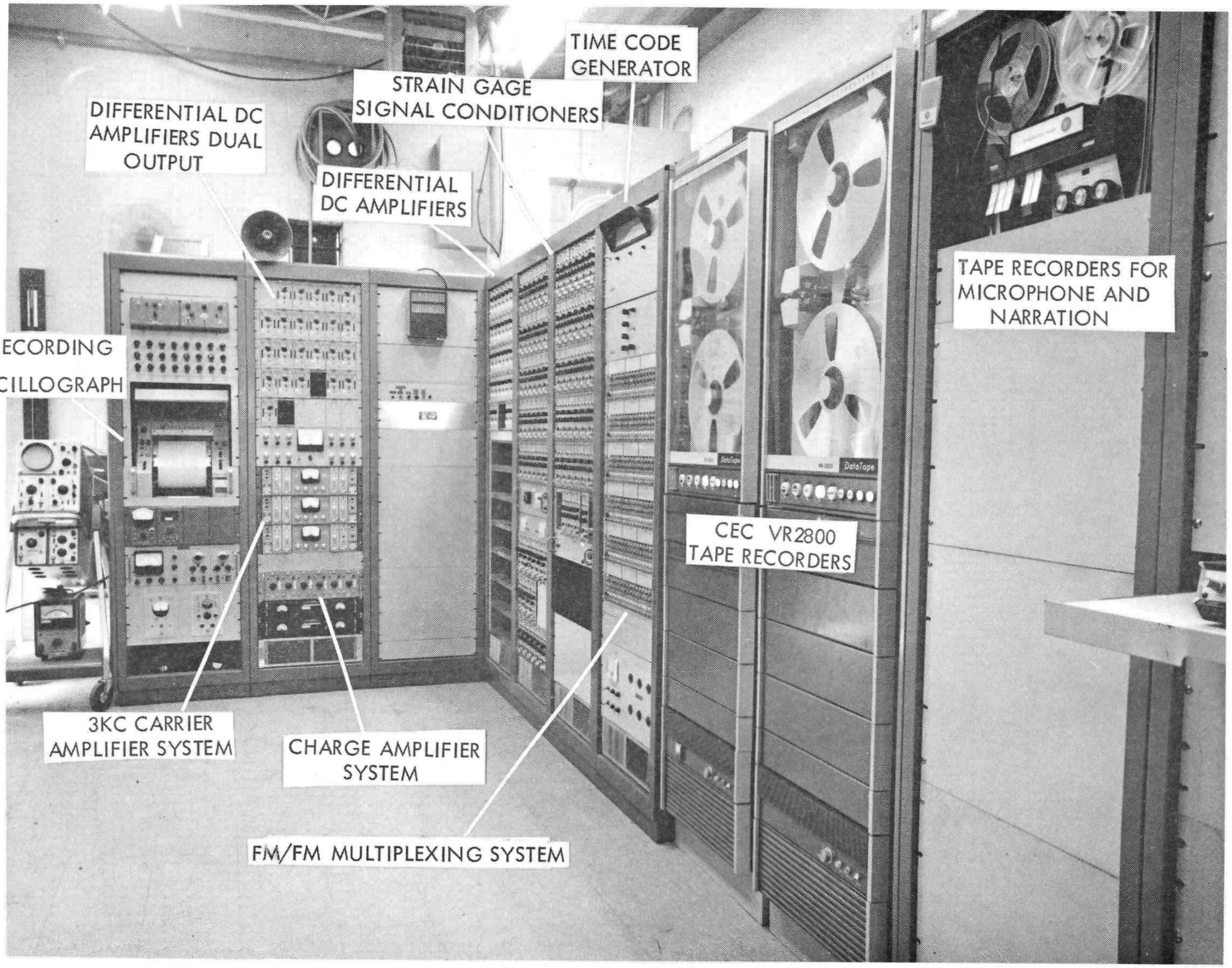


FIGURE 15

WANHES DATA ACQUISITION SYSTEM

CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954

TABLE 3

COMPLETED EXPERIMENTS - SEAL PERTURBATION TEST SERIES

Core Pressure Drop	Number of Seals Vented	--- Core Inlet Pressure (psia) --- 300	500	700
50	0	17a	18a	---
	4	17b	18b	---
	8	17c	18c	---
	12	17d	18d	---
	16	---	---	---
90	0	17e	19a	---
	4	17f	19b	---
	8	17g	19c	---
	12	17h	19d	---
	16	---	---	---
130	0	18e	19e	21a
	4	18f	19f	21b
	8	18g	20b	21c
	12	18h	20c	21d
	16	22c	22b	22a

perturbations were imposed on ambient temperature reactor operating conditions. Perturbation of the normal operating condition was achieved by successively venting groups of four seals commencing at the aft end of the reactor. The experiments conducted and their respective test designation are shown in Table 3. They were conducted in a systematic manner in order of increasing core inlet pressure, core pressure drop, and number of seals vented. This technique permitted a cautious approach in determining reactor stability as a function of these three independent variables in that the conditions conducive to reactor instability are enhanced by increasing pressure drop, core inlet pressure, and number of vented seals.

1. Seal Pressure Distribution

Seal pressures were measured with Barton differential pressure gauges which were referenced as shown in Figure 16. The differential pressure across one or more seals was measured and the absolute seal pressure determined by successively subtracting this value from the reference or seal pressure above it. It should be noted that all seal pressures were then referenced against core inlet pressure. This pressure was measured by three separate instruments: strain gauge pressure transducer P703, pneumatic pressure transmitter PT-2, and a Heise gauge. The accuracy of this measurement and the entire seal pressure profile could be further checked by calculating the aft end pressure (P710), by successive subtraction of the seal differential pressures from the core inlet pressure (P703), and comparing this with the measured value. The aft end pressure was also measured by three separate instruments: strain gauge pressure transducer P710, pneumatic pressure transmitter PT-3, and a Heise gauge. The values of the Barton differential pressure gauges and Heise gauges were recorded on photographic film approximately every two seconds. These measurements are estimated to be within 3 percent of the true value, for 95 percent confidence, for all pressure levels.

A parallel seal pressure measurement system of 0 to 50 psid differential pressure transducers were also employed. This system is depicted by the dotted lines in Figure 16. The accuracy of this means of seal pressure measurement was previously reported as 8 percent of the average value at the 95 percent confidence level (WANL-TME-792). The

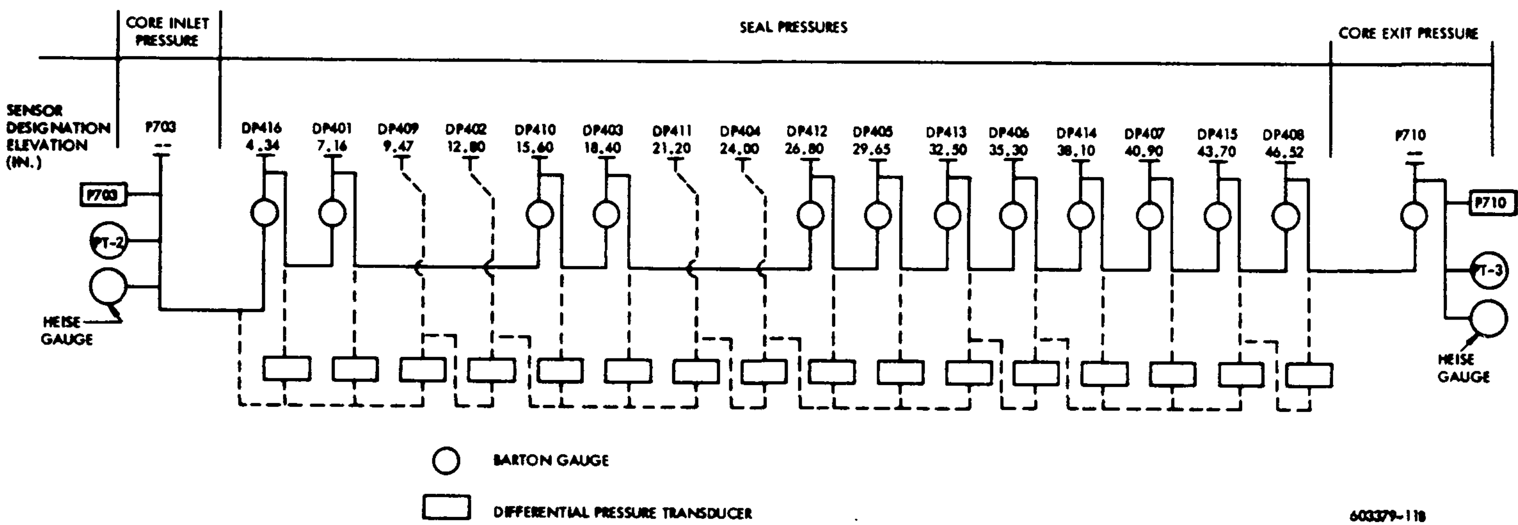


FIGURE 16

SEAL PRESSURE MEASUREMENT SCHEMATIC

results obtained are in generally good agreement with the data as measured by the Barton pressure transducers. However, no attempt was made to calculate an average seal profile as measured by both systems because of the generally superior results of the Barton system and because of incomplete pressure measurements due to differential pressure transducer failure.

Seal pressure profiles are graphically presented in sets of perturbed and unperturbed operating conditions. Figures 17, 18, and 19 show profiles attained for core pressure drop of 130 psi. For clarity, only three profiles are presented in each figure, namely, an unperturbed control test, and tests with the last 8 and 16 seals vented. Two comparisons are shown between unperturbed tests and 12 vented seals for core inlet pressures of 300 and 500 psia and core pressure drops of 90 psi. Data for these tests and those not graphically displayed are presented in Appendix A.

In all cases, the effect of successive venting is apparent in the seal profiles. A controlled perturbation of increasing severity was successfully achieved. The maximum decrease in seal pressure occurred in the 30-inch elevation region and was of the order of 30 psi for core pressure drops of 130 psi. A maximum of 0.35 lb/sec of hydrogen was vented from the seals through "pressurizer probes" to attain this pressure decrease. Further decreases in seal pressure could not be attained due to a choked flow condition in the probes.

2. Core Interelement Pressure Distribution

Core interelement pressures were measured through probes between elements by differential pressure transducers located on the core support plate. Generally, the pressures were monitored at three azimuthal, five axial, and four radial positions, as shown in Table 2. The differential pressure transducers at each axial station were referenced against the seal pressure at the same elevation. Hence these pressures are based on core inlet pressure in a manner similar to that noted in the previous section. A more detailed discussion of this measurement technique is found in WANL-TME-792.

[redacted]

Astronuclear Laboratory

WANL-TME-1207

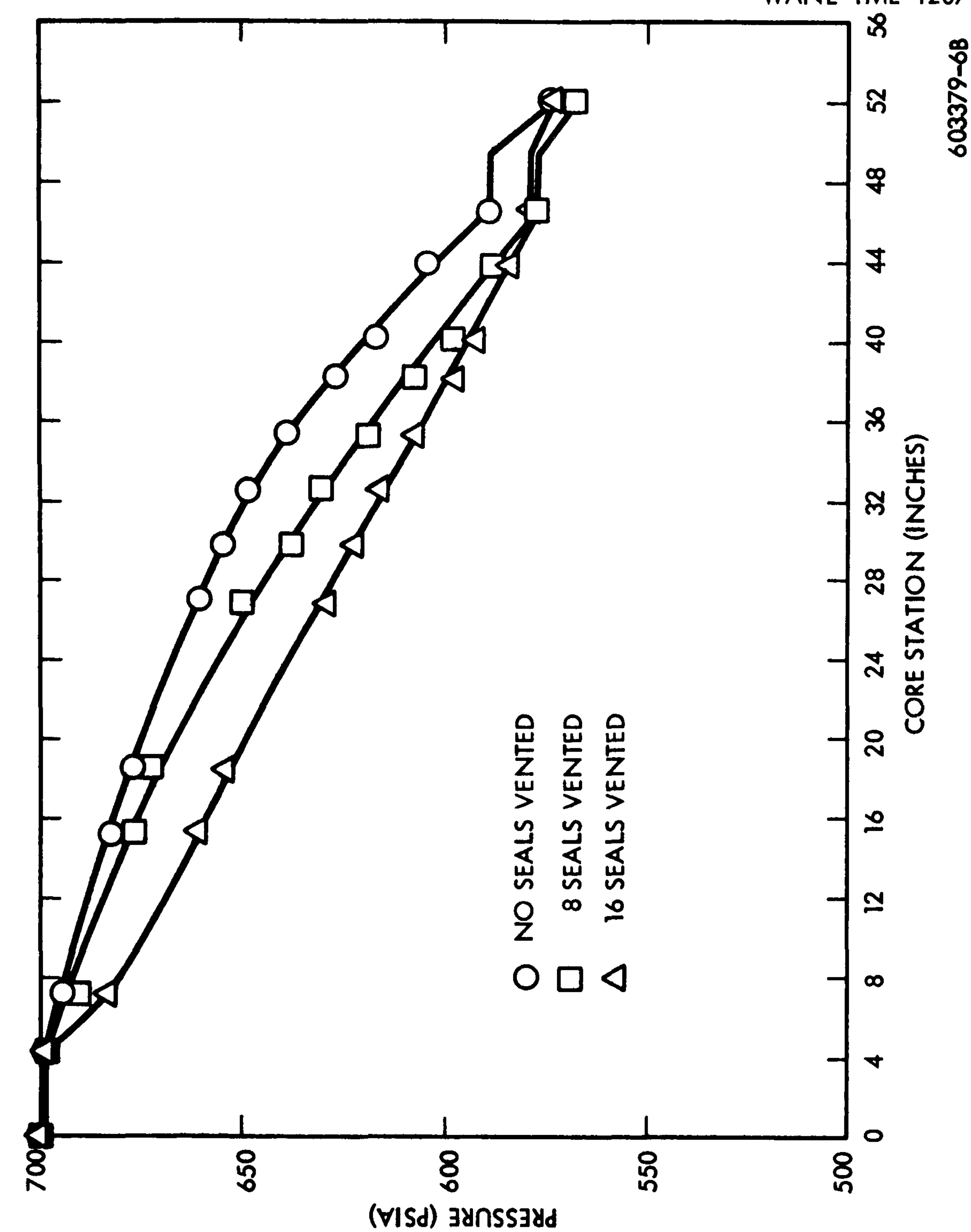
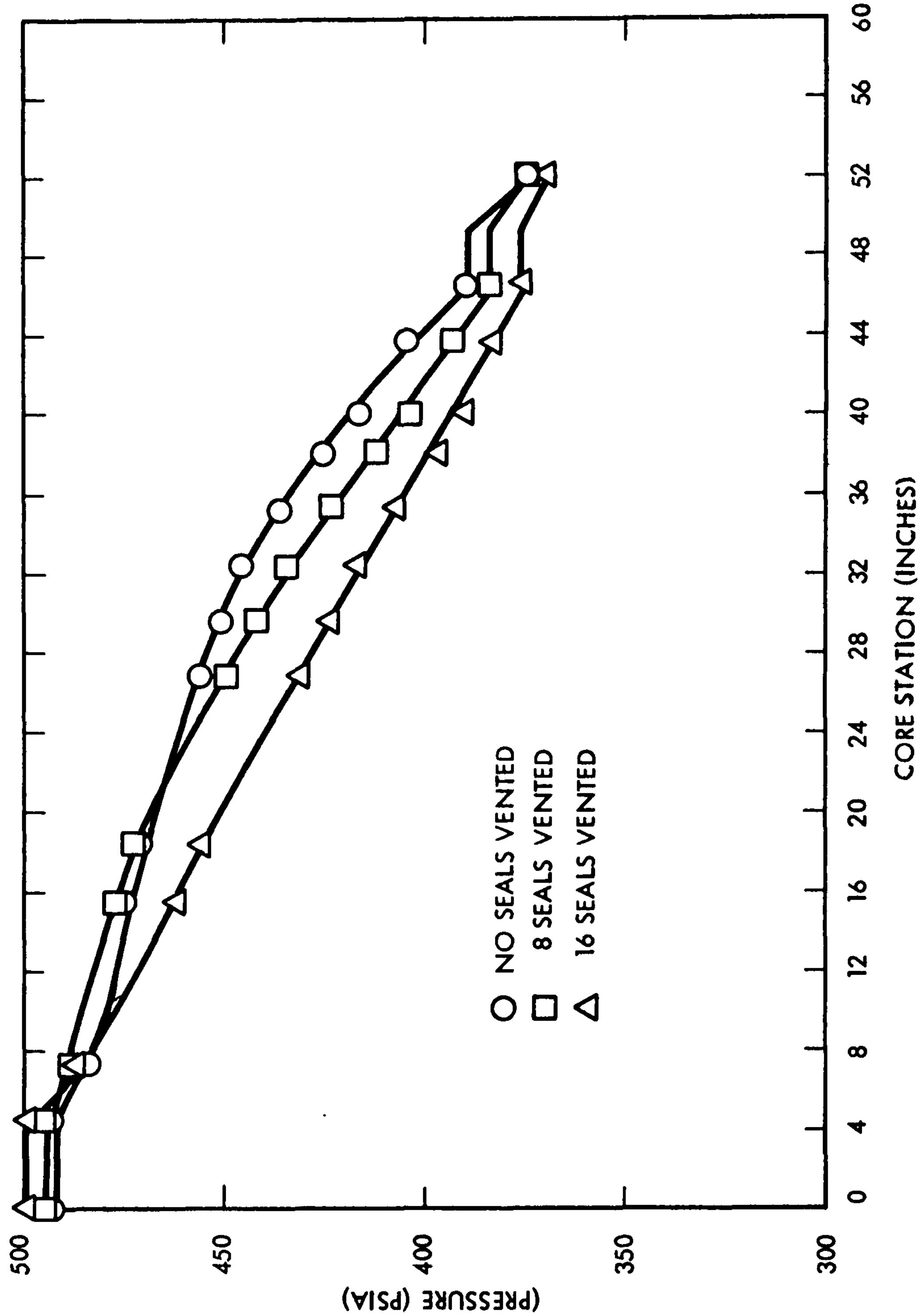


FIGURE 17

SEAL PRESSURE PROFILES - FFL-9-21a, 21c, 22a

[redacted]



603379-8B

FIGURE 18

SEAL PRESSURE PROFILES - FFL-9-19e, 20b, 22b

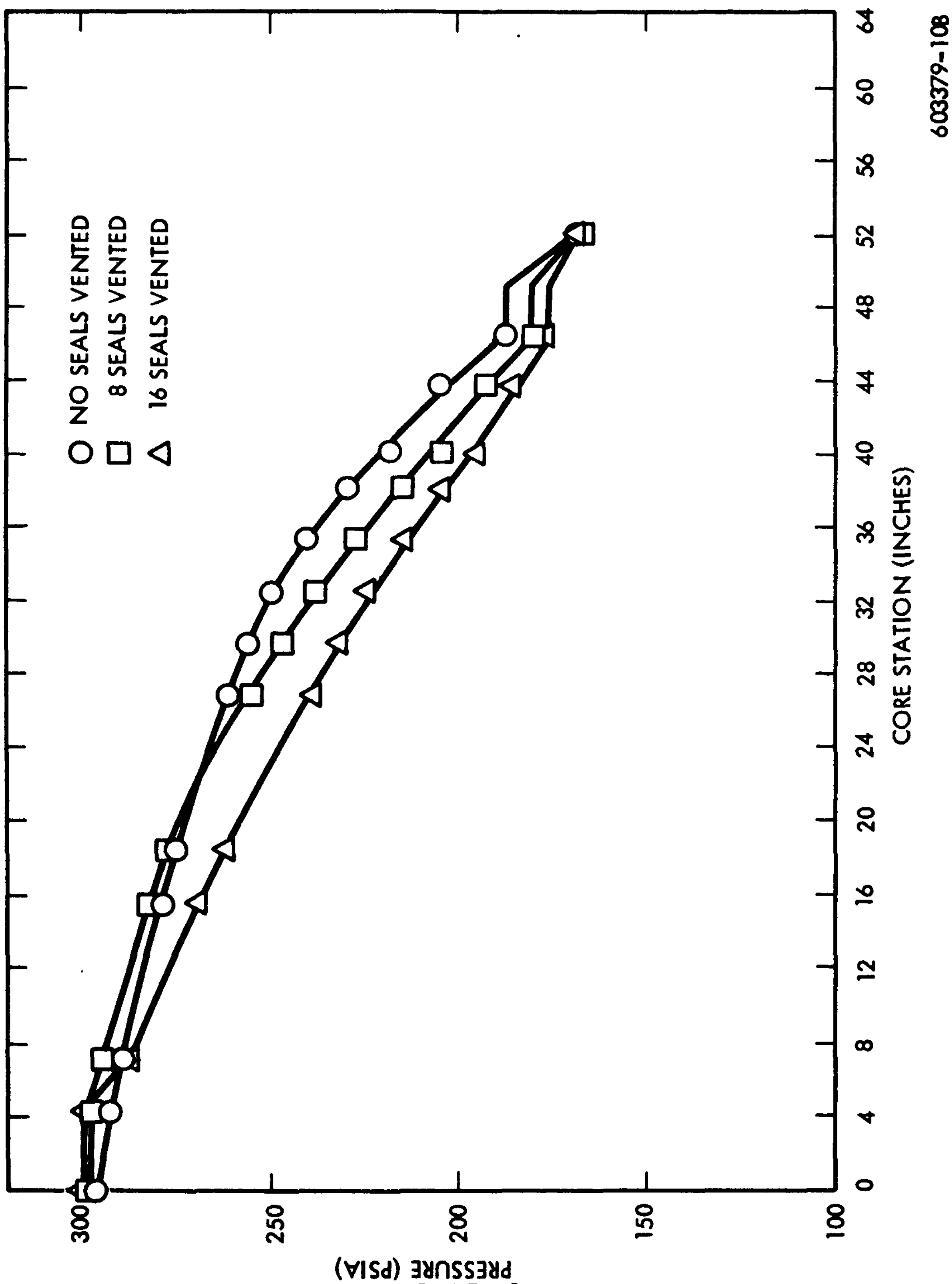


FIGURE 19

SEAL PRESSURE PROFILES - FFL-9-18e, 18g, 22c

Detailed pressure measurements for the pertinent tests performed are tabulated in Appendix B. Figures 20 through 31 present core radial pressure profiles and isobar plots for core inlet pressures of 300, 500, and 700 psia, core pressure drops of 130 psi, and unperturbed and 16 seal vent conditions. Additional pressure profiles are presented in Appendix B. The core pressure profiles drawn through the experimental points are based on several considerations. These are:

(a) Best fit to experimental points.

(b) Consideration of isobar plots.

(c) Consideration of a physically consistent flow model for all tests.

(d) Theoretical considerations.

One must examine each of these considerations with full realization of the uncertainties. These are:

(a) Lack of sufficient pressure data radially and axially which necessitated large interpolations of data.

(b) Lack of definition or basic knowledge of the critical aft end of the core with its rising pressure gradient.

(c) Inaccuracy inherent in making the two dimensional representation or projection of the three dimensional flow patterns in the reactor.

(d) Lack of sufficient azimuthal probes to more nearly approximate the azimuthal variations in pressure.

The radial pressure profiles and isobar plots are based on the assumption of azimuthal symmetry. This assumption appears to be correct, within the accuracy of interelement pressure measurements, based on the data available to date. Hence the pressure profiles and isobar plots are drawn as the best fit to all points, at a given elevation, irrespective of their azimuthal position. In addition, axial pressure profiles were considered to insure a physically consistent set of radial profiles in progressing from elevation to elevation. Finally, the pressure profiles must yield a consistent isobar plot, that is, isobars may not cross one another (i.e., it is impossible to have two pressures existing at the same point in space) and should form a reasonable family of curves consistent with a flow pattern. It is assumed that streamlines are orthogonal to lines of constant pressure in accordance with the classical relations between velocity potential and stream function.

The sparsity of pressure probes and large interpolations of data leave the analyst with some latitude in drawing the core pressure profiles and isobar plots. The curves presented should not be taken as a precise mapping of core flow phenomenon but rather as a consistent and reasonable description of the overall flow patterns.

The profiles generally indicate radial inflow from the seal region along the first four-fifths of the core and radial outflow along the remaining fifth. The degree of outflow observed along the last fifth of the core periphery appears to increase in proportion to the severity with which the seals are vented. This is inferred from the general widening and deepening of the "trough" extending from the aft end corner of the core up into its interior and the generally increased radial pressure gradient. As has been previously noted,[11] this outflow can be construed from the high pressure area existing at the 46-inch elevation. In the majority of the isobar plots drawn, a high pressure area is shown extending along the centerline from approximately the 22-inch elevation to the aft end. The area of high pressure is relatively flat, physically analogous to a plateau. This is indicated by the fact that the centerline probes at the last three elevations are within 5 psi of one another (a value of the same order of magnitude as the error of measurement). However, in at least one instance (FFL-17-21a) a distinct pressure rise is shown to exist. A full understanding of this flow phenomenon remains to be achieved.

The pressure profiles and flow patterns below the 46-inch elevation are uncertain. This is largely due to the unknown interaction of the 3/4-inch undercut at the aft end of the elements and the interlocking support block system. Should the undercut area provide an essentially low flow impedance while the support blocks form essentially a barrier, there would be considerable outflow at the core periphery from the 48 to 52-inch elevations. However, should

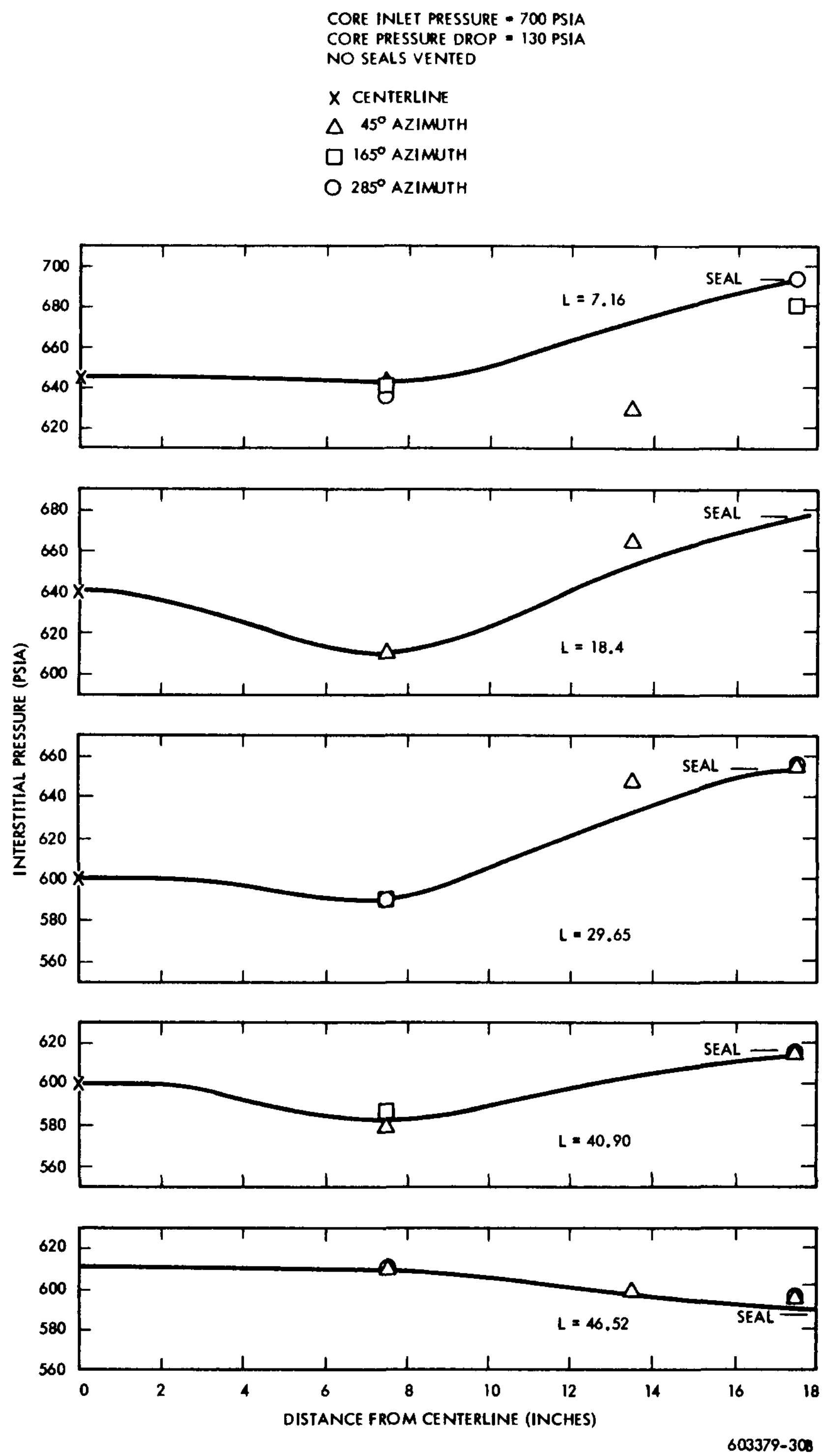
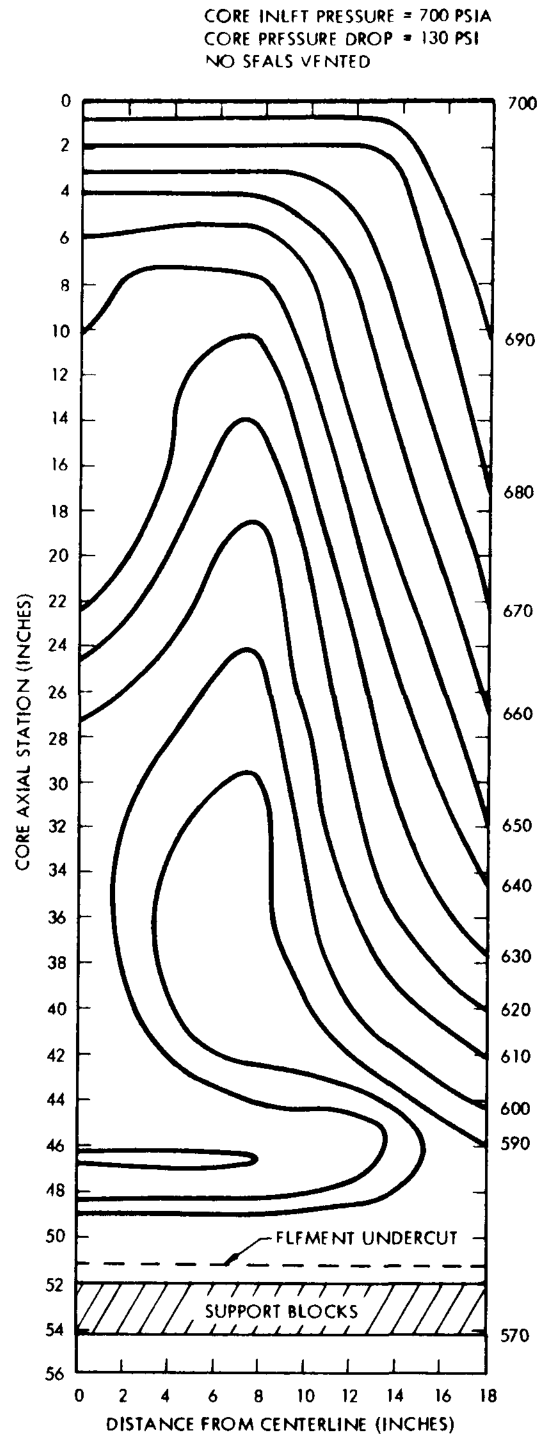


FIGURE 20

CORE INTERELEMENT PRESSURES - FFL-9-21a



603379-188

FIGURE 21

ISOBAR MAP OF CORE - FFL-9-21a

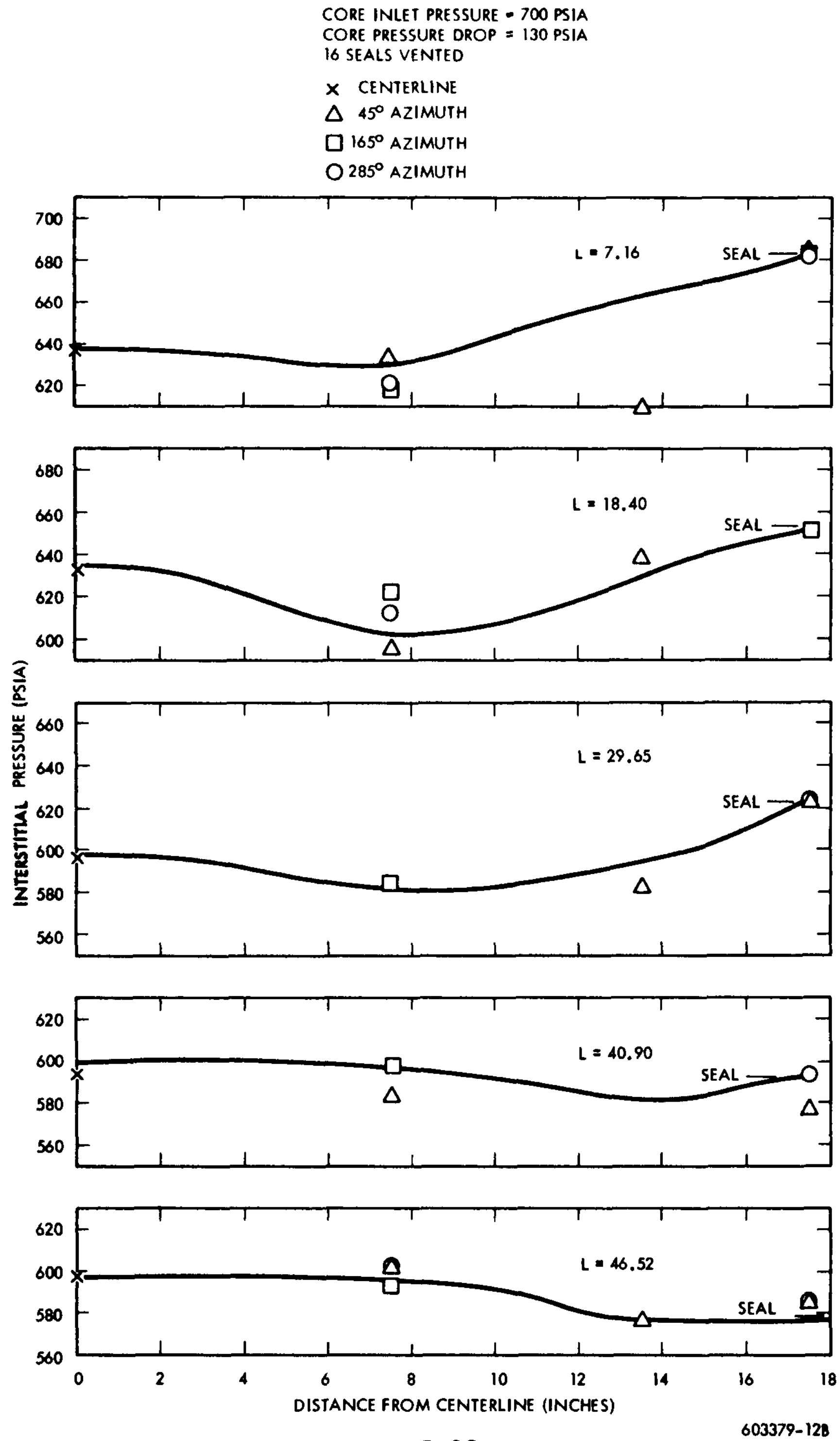
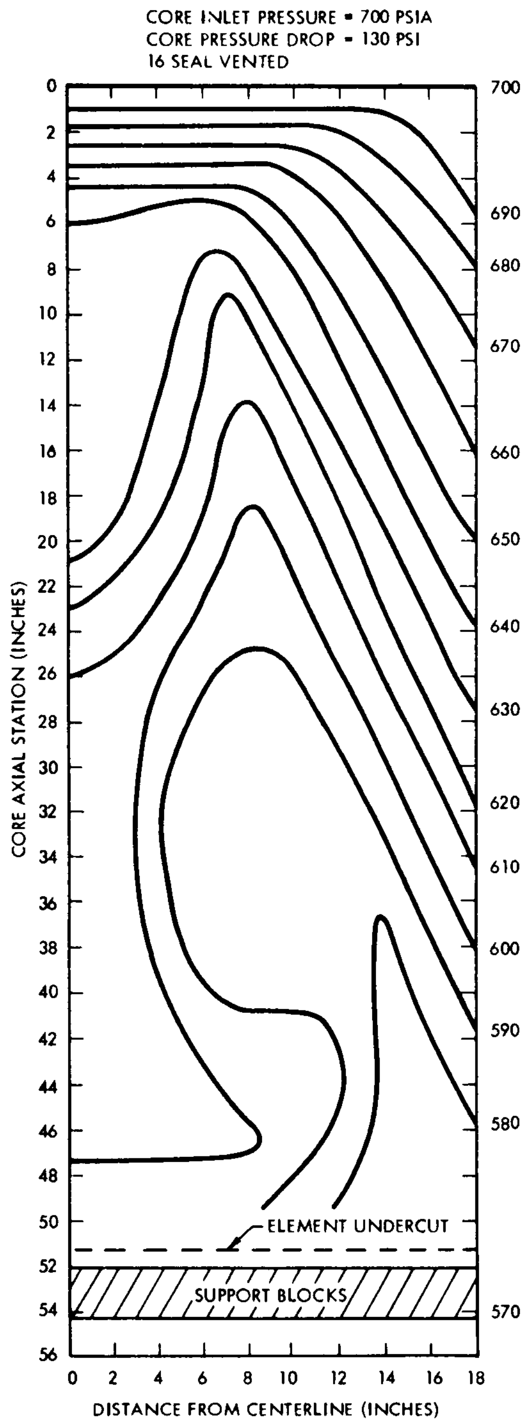


FIGURE 22

CORE INTERELEMENT PRESSURES - FFL-9-22a



603379-21B

FIGURE 23

ISOBAR MAP OF CORE - FFL-9-22a

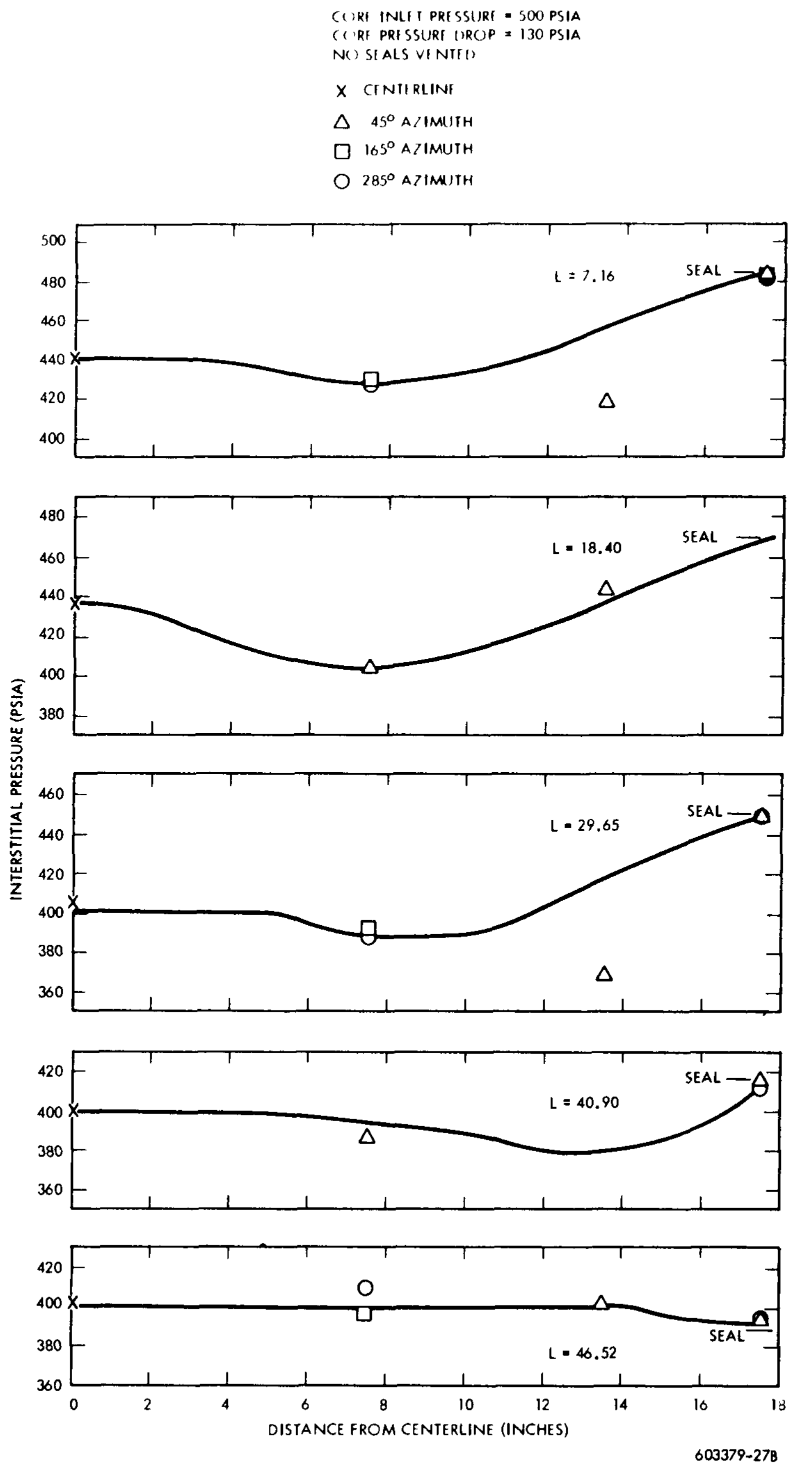


FIGURE 24

CORE INTERELEMENT PRESSURES - FFL-9-19e

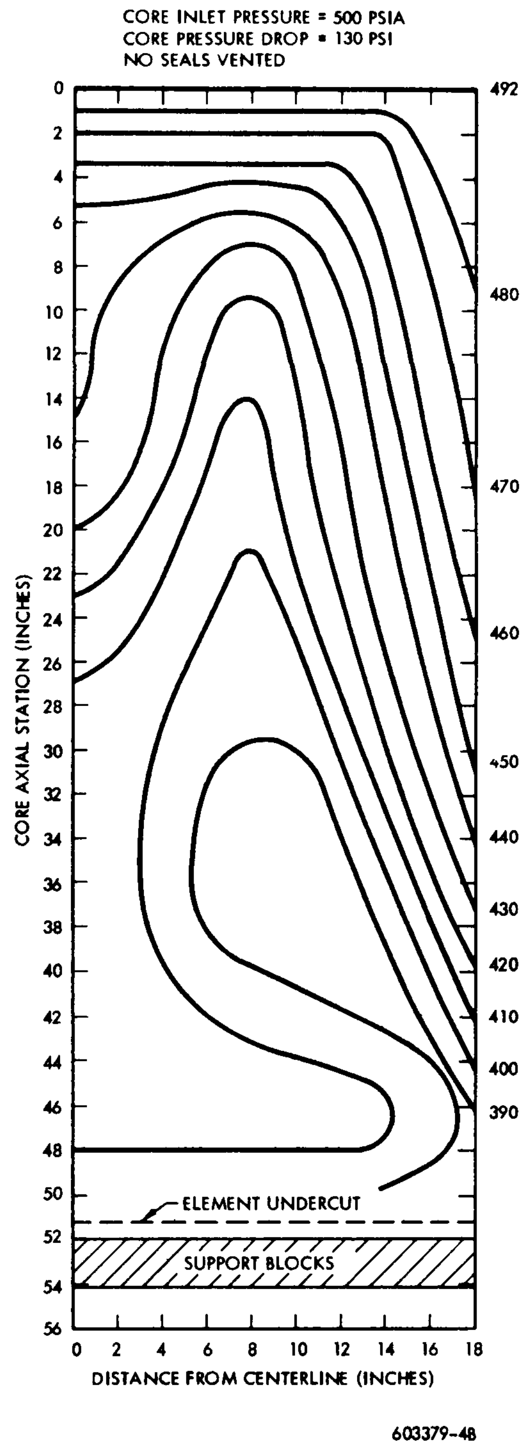


FIGURE 25

ISOBAR MAP OF CORE - FFL-9-19e

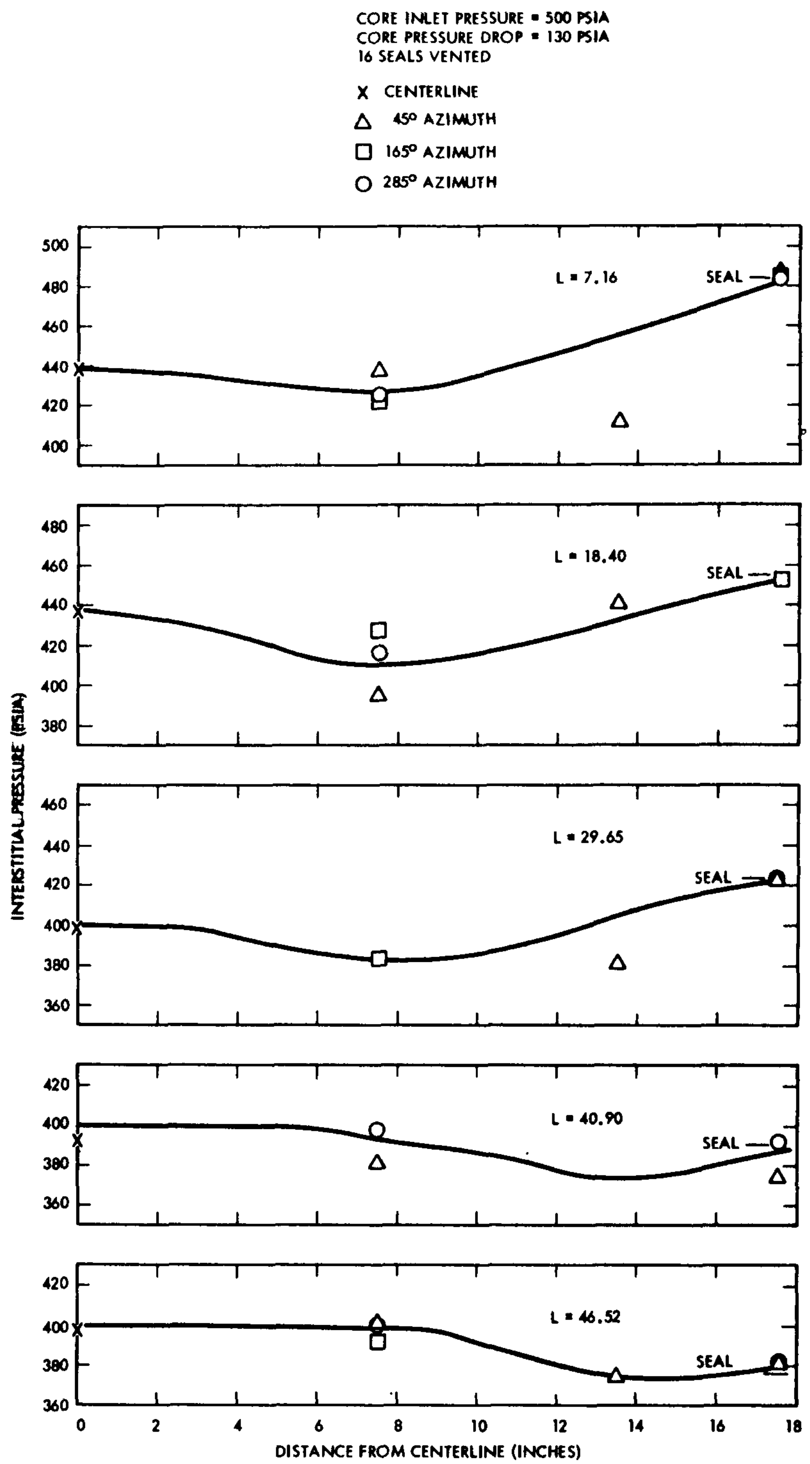


FIGURE 26

CORE INTERELEMENT PRESSURES - FFL-9-22b

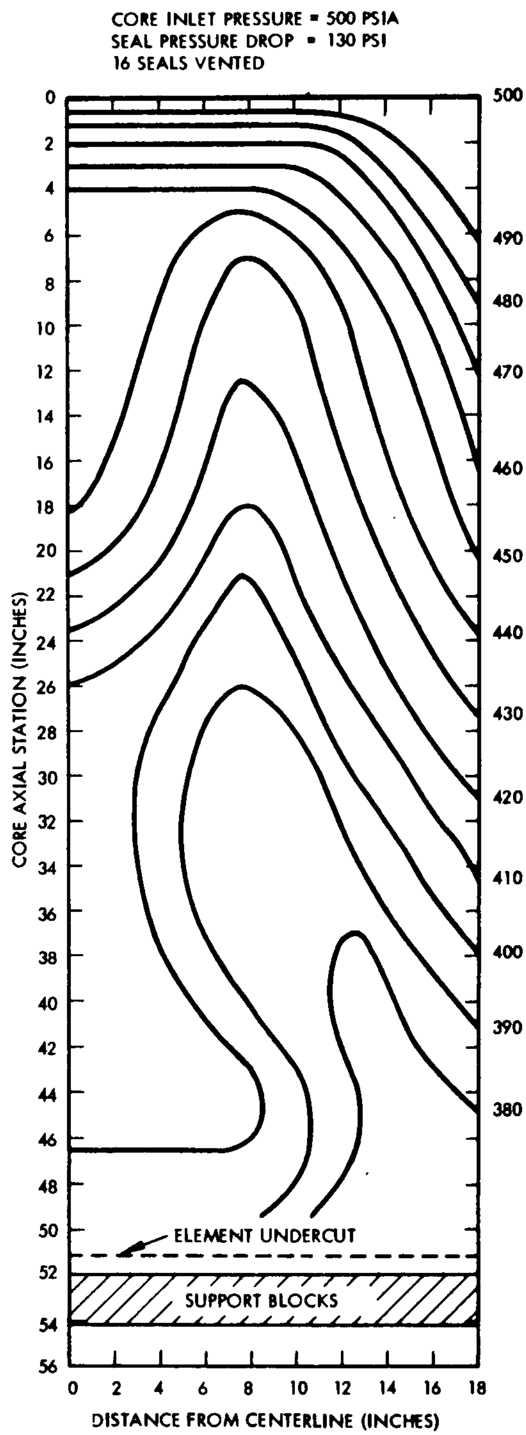
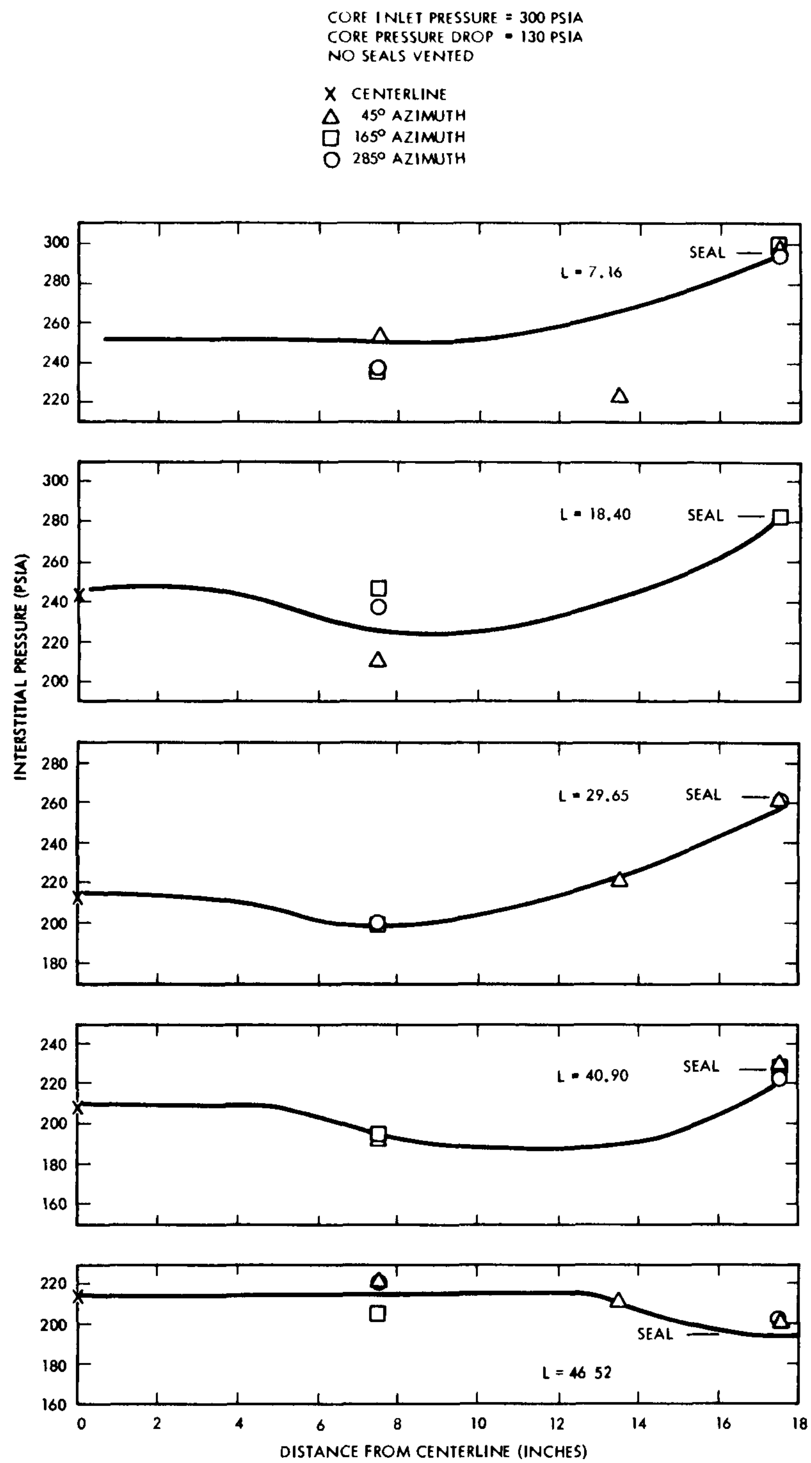


FIGURE 27

ISOBAR MAP OF CORE - FFL-9-22b



603379-32B

FIGURE 28

CORE INTERELEMENT PRESSURES - FFL-9-18e

[redacted]

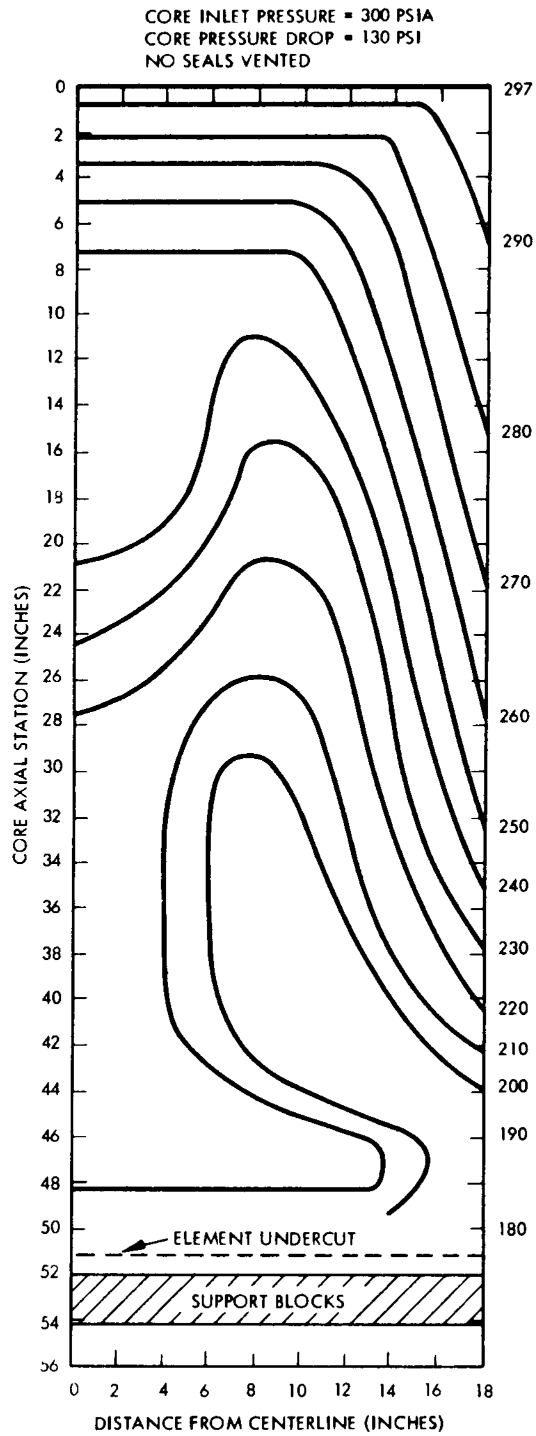


FIGURE 29

ISOBAR MAP OF CORE - FFL-9-18e

[redacted]

[redacted]

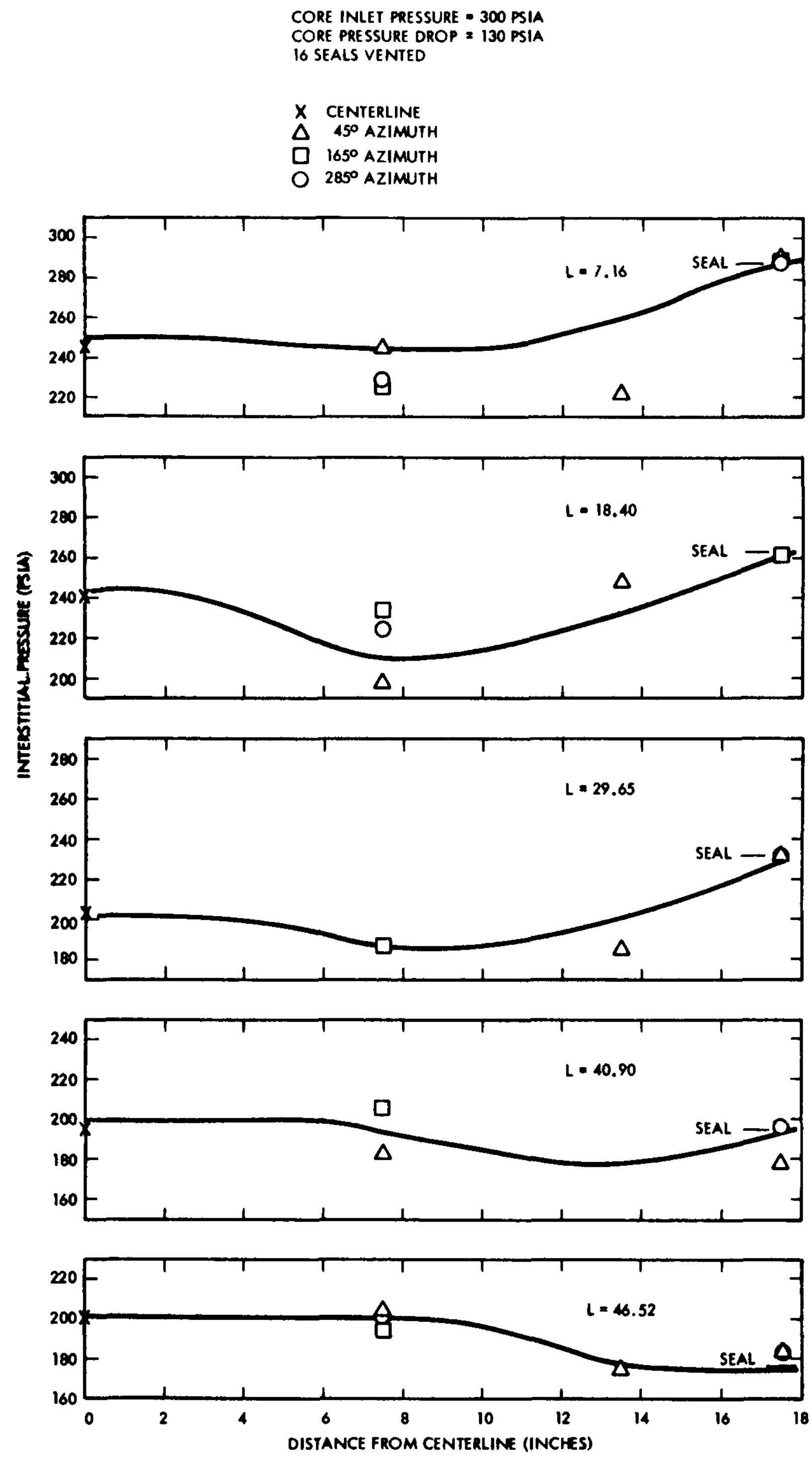
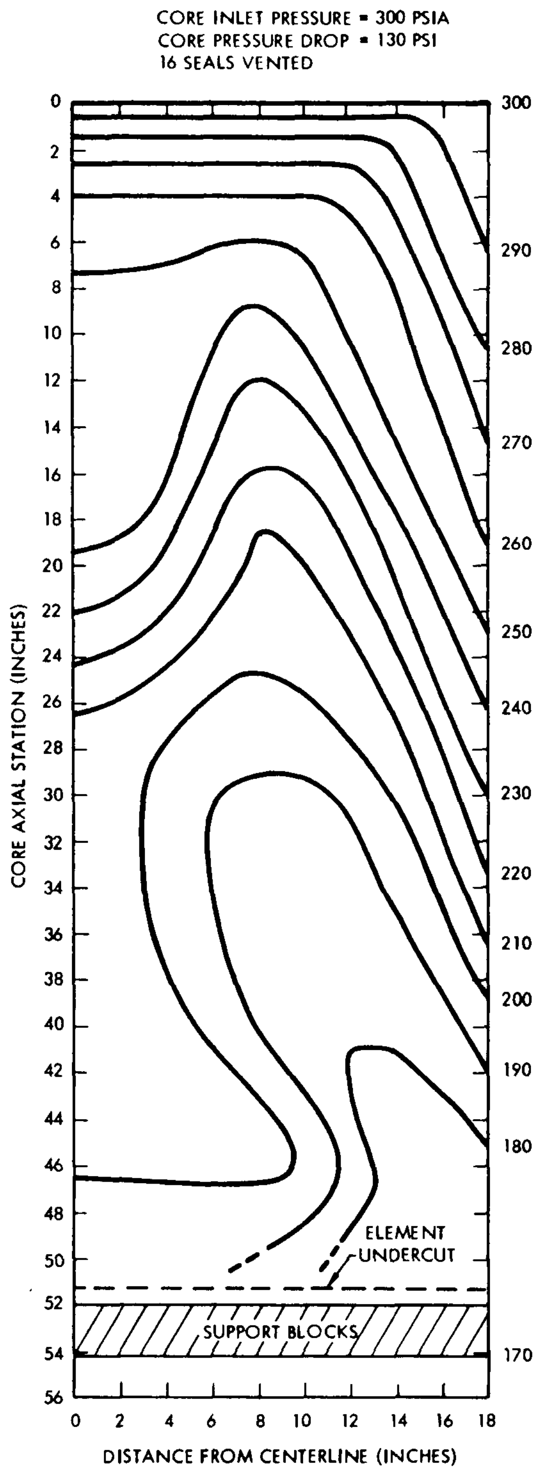


FIGURE 30

CORE INTERELEMENT PRESSURES - FFL-9-22c

[redacted]

[redacted]



603379-20B

FIGURE 31

ISOBAR MAP OF CORE - FFL-9-22c

[redacted]

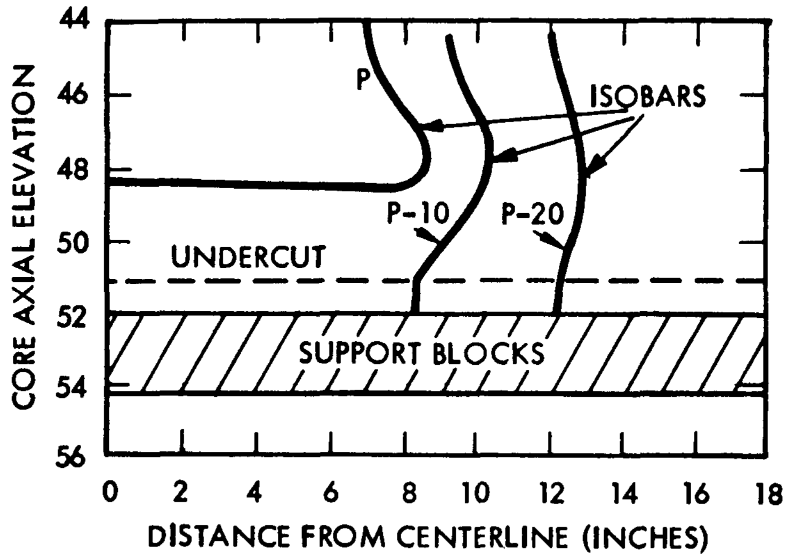
the support block flow impedance be more nearly equal to the flow impedance of the undercut, a more axial flow could be expected. The two extremes are shown in the form of isobar plots in Figure 32. Obviously, a flow scheme intermediate to the two shown could exist depending on the relative flow impedances of the two areas.

Comparison of the seal pressure profiles with axial plots of core interelement pressures readily indicate the degree of fluid core bundling achieved. By fluid core bundling we mean the radial forces acting on core elements due only to radial pressure gradients. Figures 33 and 35 present axial plots for a nominal core inlet pressure of 700 psia and nominal core pressure drop of 130 psi at unperturbed and 16 seal vent conditions. Core bundling pressures were found by determining the pressure difference from one axial profile to another. These results are plotted in Figures 34 and 36. Maximum positive core bundling pressure (positive bundling pressure is taken to mean that the net forces act toward the core centerline) for the unperturbed condition is found between the seal and the 7.5-inch radius at the 12-inch elevation and is of the order of 68 psi. A positive bundling pressure existed between the seals and the 7.5-inch radius from the core inlet to the 46-inch elevation. A negative bundling pressure was apparent between the core centerline and the 7.5-inch radius. The maximum negative bundling pressure calculated is 28 psi at the 20-inch elevation. Core bundling pressures for the 16 seal vent condition were similar to that observed for the unperturbed condition. However, positive bundling pressures were approximately 20 percent lower, and negative bundling pressure approximately 20 percent higher than the unperturbed condition. The net core bundling pressure, from seal to core centerline, for both perturbed and unperturbed conditions, was positive with the exception of the last 8 to 10-inches of the core, where a net negative bundling pressure was observed.

3. Flow Rates

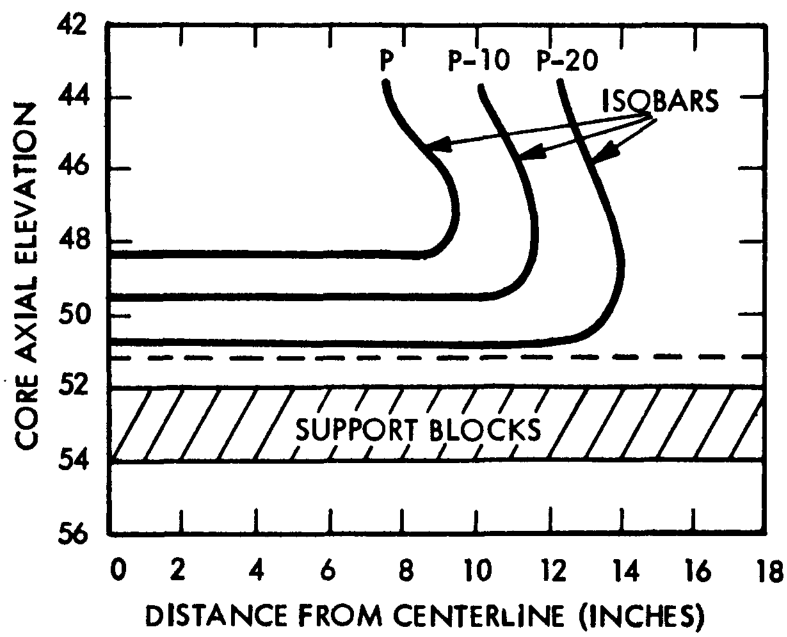
During unperturbed steady state runs only two fluid streams are of concern, namely, reflector inlet flow as measured by orifice meter 0-1, and vessel outlet flow as measured

[redacted]



FLOW PATTERN

SUPPORT BLOCK FLOW IMPEDANCE ≫ UNDERCUT FLOW IMPEDANCE



FLOW PATTERN

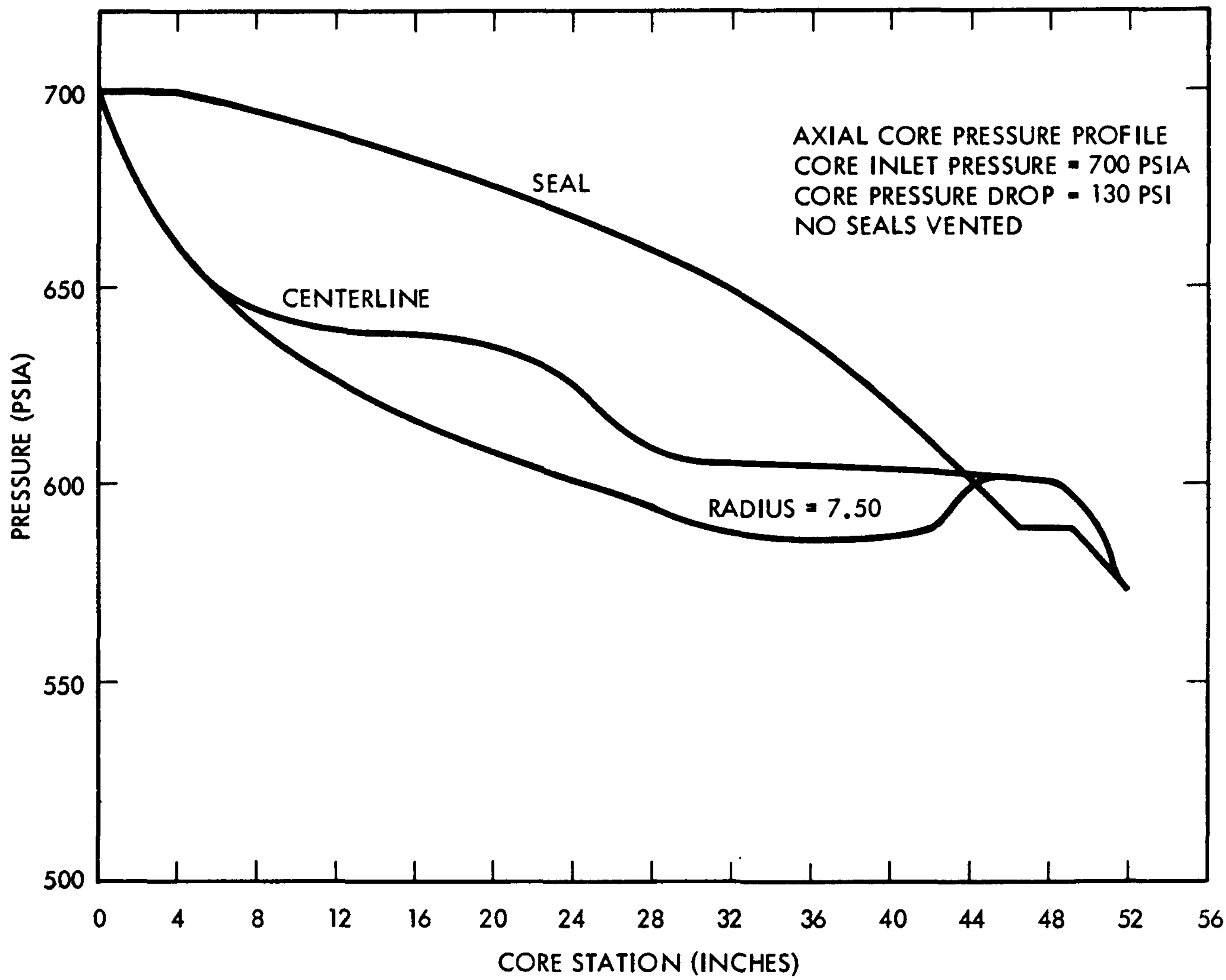
SUPPORT BLOCK FLOW IMPEDANCE ≤ UNDERCUT FLOW IMPEDANCE

FIGURE 32

603379-22B

FLOW AT AFT END OF CORE

[redacted]



603379-25B

FIGURE 33

AXIAL CORE PRESSURE PROFILES - FFL-9-21a

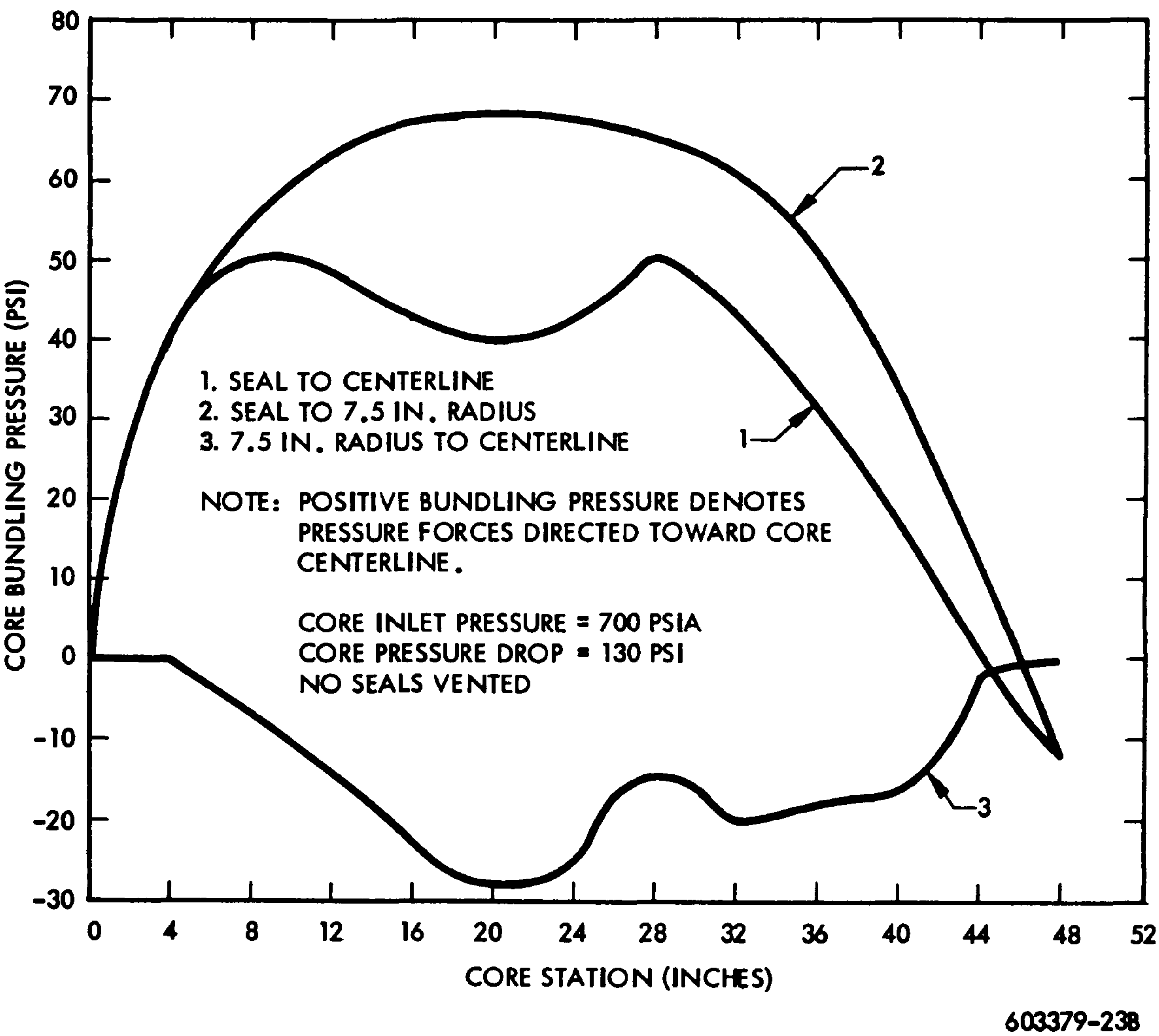
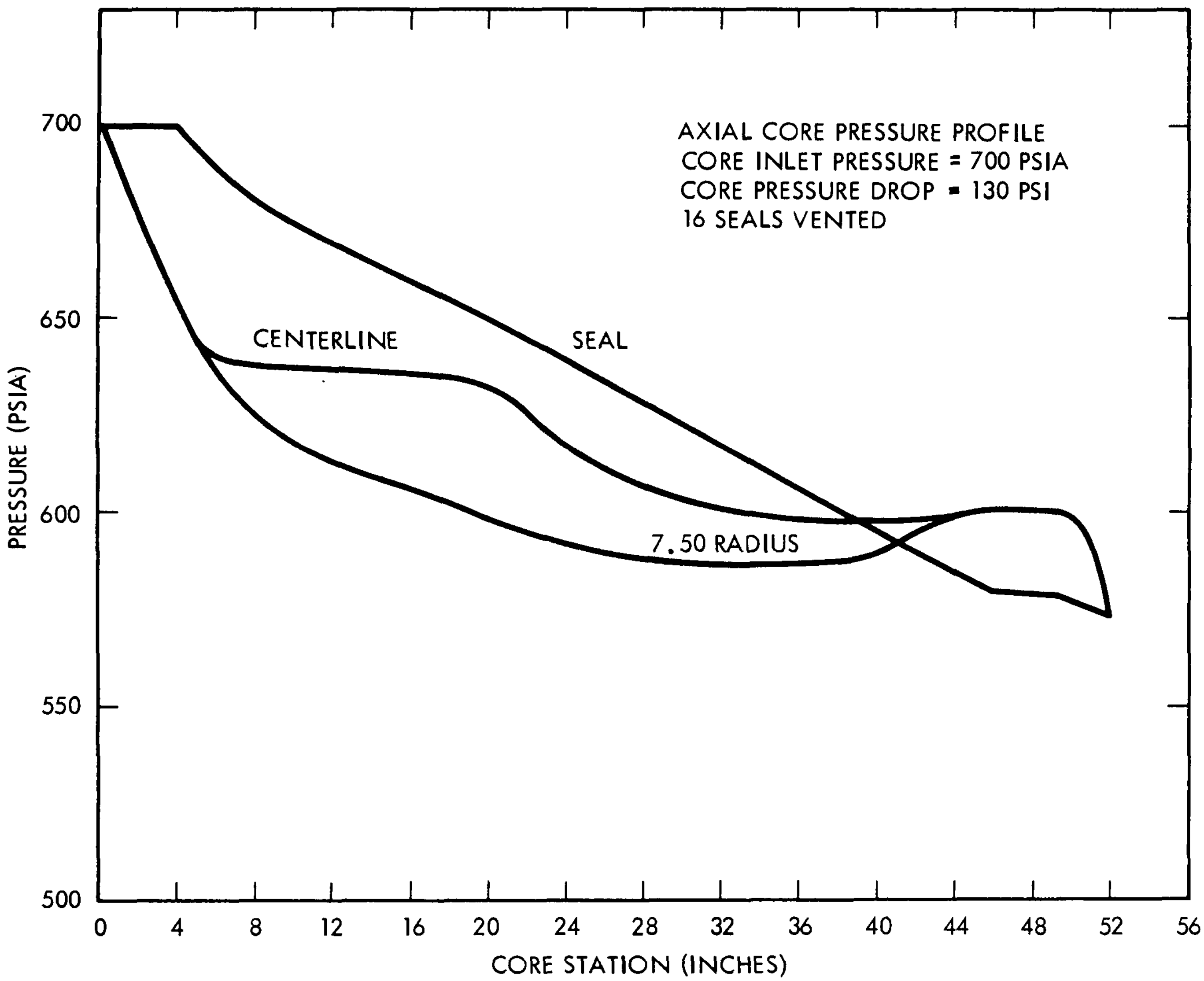


FIGURE 34

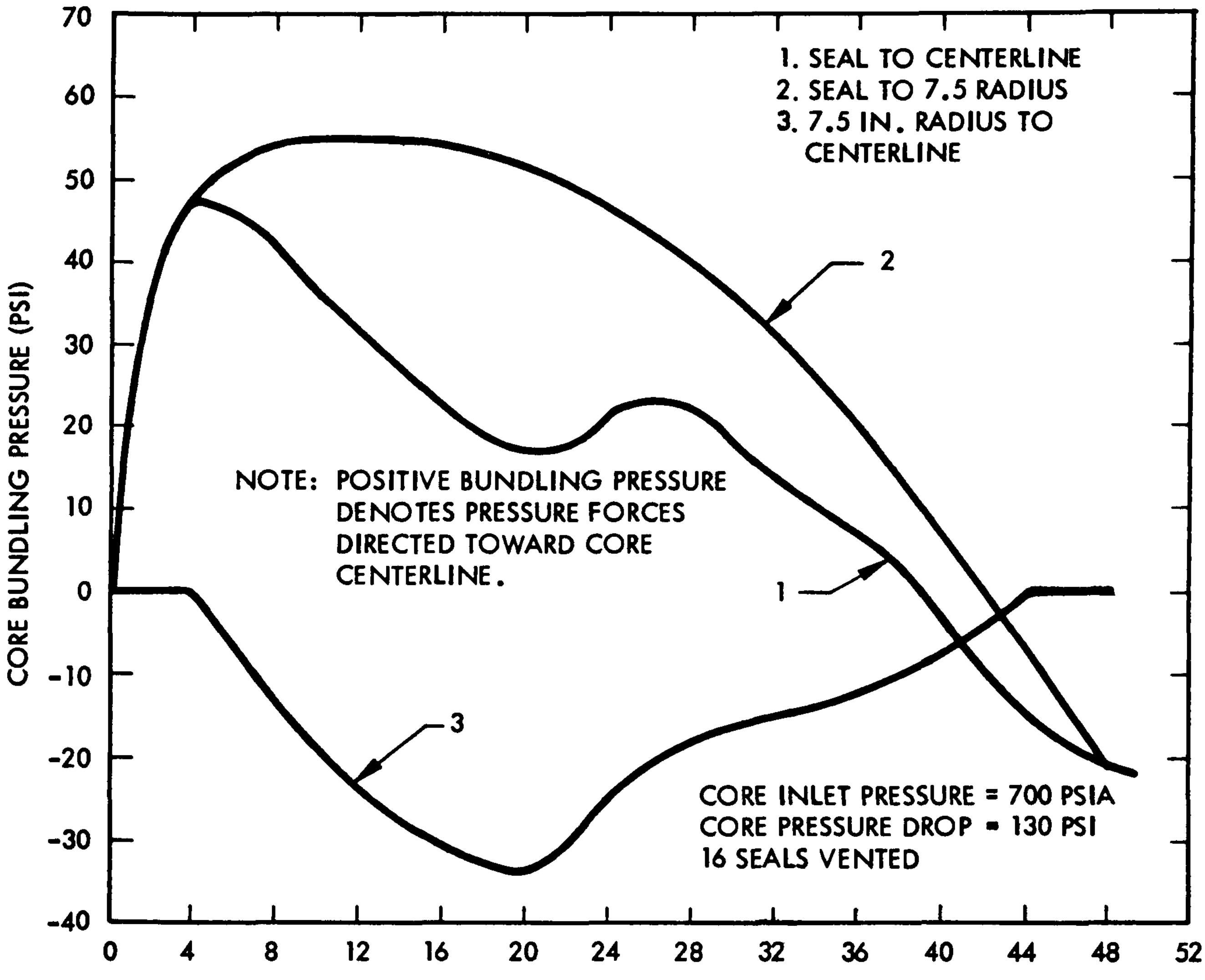
FLUID CORE BUNDLING PROFILES - FFL-9-21a



603379-24B

FIGURE 35

AXIAL CORE PRESSURE PROFILES - FFL-9-22a



603379-26B

FIGURE 36

FLUID CORE BUNDLING PROFILES - FFL-9-22a by orifice meter 0-3 (see Figure 11). For unperturbed steady state runs these two measurements agreed within 2 percent. A third fluid stream is introduced during seal perturbation runs. The amount of hydrogen vented through the seal pressurizer probes was determined from the difference between the reflector inlet flow and the vessel outlet flow. A summary of the mass flow data is presented in Table 4. The mass flow rates for unperturbed steady state runs are plotted against the product of core inlet pressure and core pressure drop in Figure 37. The curve is the previously reported best fit curve for the steady state test series. Present data show excellent agreement with results previously reported.[11]

Venting the seals tended to increase reflector inlet flow and decrease vessel outlet flow. The effect became more pronounced with increasing severity of seal vent. The maximum flow rate was achieved with a core inlet pressure of 700 psia and core pressure drop of 130 psi. The flow rates were 0.778 lbs/sec at the reflector inlet, 0.433 lbs/sec at the vessel outlet and 0.345 lbs/sec vented through the seal probes.

4. Mechanical Stress, Strain and Component Movement

Data from seven lateral support springs instrumented with strain gauges were recorded. They provided data on plunger pin movement and the mechanical stability of the core. Prior to assembly the strain gauges were calibrated to give plunger pin movement in terms of the lateral support spring strain rate. It is estimated that the given values for pin movement are correct at the 95 percent confidence level to within 15 percent.[11]

Pin movement is caused by one or both of two motions: a deflection of the inner reflector barrel and a movement of the core. In general, the graphite barrel should deflect inward toward the core under the influence of the higher pressure level on its external (or outer) surface. The barrel may assume an elliptical shape under these loading conditions. The core may either broom or compress depending on such factors as pressure, core pressure drop, axial location, and flow rate. Because there were insufficient sensors available and no stationery reference point, the effects of core movement and barrel movement could not be separated.

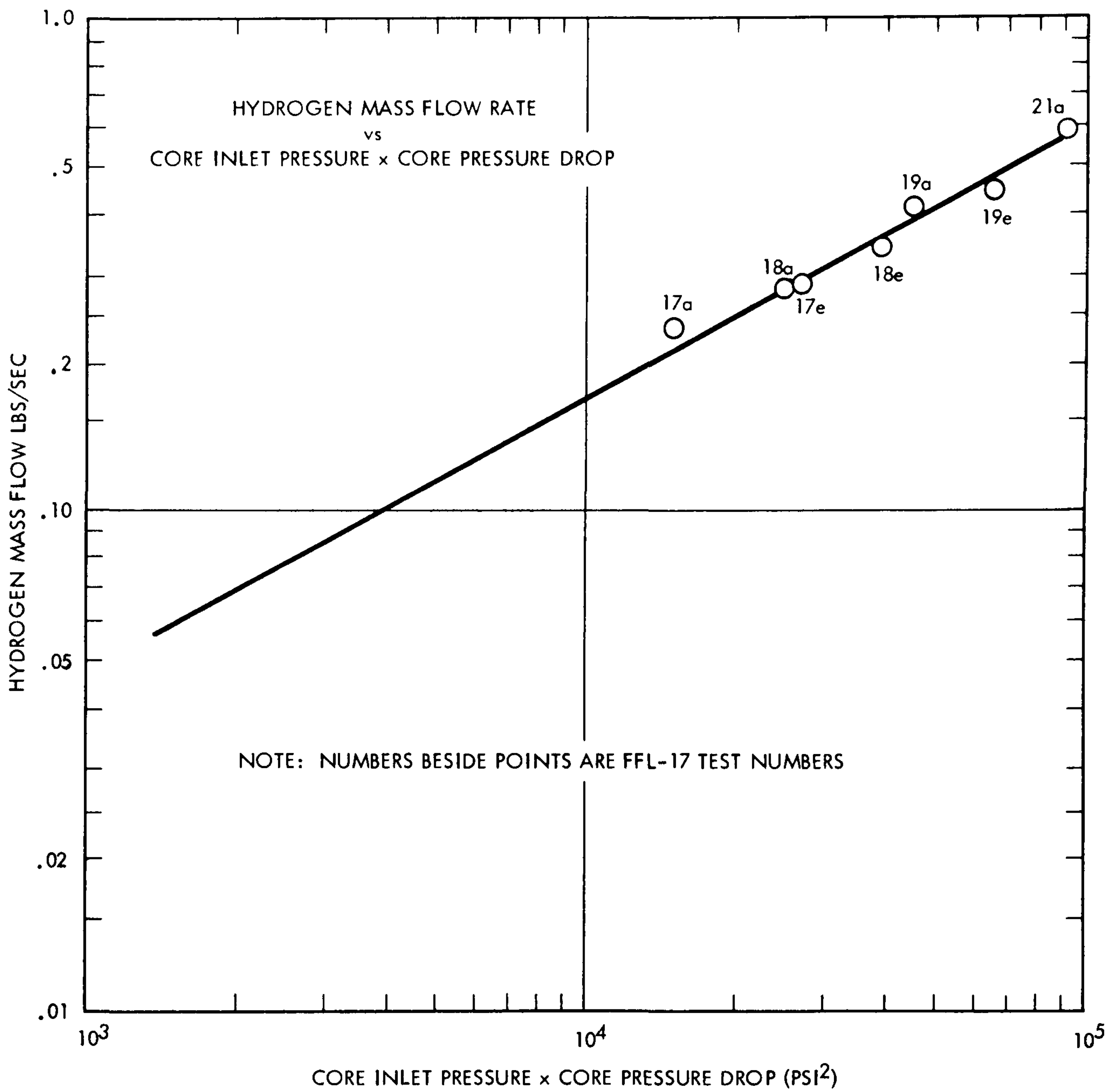
TABLE 4

MASS FLOW RATES
FFL-9 - SEAL PERTURBATION SERIES

Run No.	Core Inlet Temperature T_1 (°F)	Core Outlet Temperature T_2 (°F)	$P\,\Delta P \times 10^{-3}$	Core Inlet Pressure P_1 (psia)	Core ΔP (psi)	N_v	Core Inlet Flow M_1 lb/sec	Core Outlet Flow M_3 lb/sec	Seal Vent Flow M_5 lb/sec
17a	(70)	(70)	13.75	299	46	0	.234	.236	-.002
17b	(70)	(70)	13.75	299	46	4	.205	.183	.022
17c	(70)	(70)	13.75	299	46	8	.215	.157	.048
17d	(70)	(70)	13.75	299	46	12	.240	.152	.088
18a	83.0	83.1	19.78	494	40	0	.272	.266	.006
18b	85.3	83.9	28.00	509	55	4	.309	.272	.027
18c	83.4	82.7	25.20	504	50	8	.308	.240	.068
18d	81.5	82.3	25.20	504	50	12	.332	.205	.127
17e	(70)	(70)	26.01	299	87	0	.290	.301	-.011
17f	(70)	(70)	26.01	299	87	4	.284	.257	.027
17g	(70)	(70)	27.97	304	92	8	.306	.242	.064
17h	(70)	(70)	26.01	299	87	12	.328	.229	.099
18e	83.5	82.3	40.60	303	134	0	.341	.346	-.005
18f	83.5	82.3	40.13	304	132	4	.336	.321	.015
18g	83.5	82.7	41.04	304	135	8	.355	.288	.067
18h	81.5	79.2	40.13	304	132	12	.370	.280	.090
22c	74.4	41.5	39.60	300	132	16	.413	.262	.151
19a	92.2	85.5	51.40	514	100	0	.416	.410	.006
19b	89.9	85.5	51.40	514	100	4	.404	.362	.042
19c	87.6	85.5	45.36	504	90	8	.407	.317	.090
19d	87.6	85.5	50.90	509	100	12	.447	.314	.133
19e	87.6	85.5	65.52	504	130	0	.443	.470	-.027
19f	87.6	85.5	75.60	504	140	4	.479	.437	.042
20b	69.5	61.3	68.72	509	135	8	.491	.413	.078
20c	65.5	62.8	62.38	499	125	12	.511	.374	.137
22b	74.4	45.0	65.50	500	131	16	.632	.356	.276
21a	93.2	86.6	88.20	699	126	0	.598	.604	-.006
21b	91.0	86.6	91.00	699	130	4	.566	.543	.023
21c	91.0	85.4	92.40	699	132	8	.603	.506	.097
21d	91.0	84.4	91.70	699	131	12	.636	.472	.164
22a	80.4	56.3	88.25	699	126	16	.778	.433	.345

( ) Indicates estimated values.

N_v Indicates number of seals vented.



603379-1B

FIGURE 37

HYDROGEN MASS FLOW RATE AS A FUNCTION OF CORE INLET PRESSURE AND CORE PRESSURE DROP

Figures 44 through 49 in Appendix C illustrate typical results for the test series. Apparent pin movement is plotted against axial core location at two azimuthal positions, 50° and 270°. The fact that the strain curves do not coincide indicates an unsymmetric deflection of either the core or the barrel. The curves were drawn through the measured values and reflect the general shape found and reported[11] in the earlier phases of this test series.

As previously reported[11], pin movement increased with pressure level and pressure drop across the core and barrel. The effect of venting the seals on pin movement is indeterminate. It is evident that venting the seals will tend to increase any inward movement of the inner reflector. Similarly the decreased bundling pressure on the core would tend to promote any tendency for the core to "broom". The result of these two effects, acting independently or in concert, would tend to increase pin movement. No trend in this direction could be conclusively drawn from the data. The obscuring feature might be that the plunger pins do not return to their original position at the end of each test. This could be caused by friction or the plunger pin cocking in the hole. Rebalancing the strain grids prior to each test effectively assigns a new zero reference on which pin movement is based. Hence further measurements are distorted by the false base. A study of the pin movement data (Table 7, Appendix C) indicates that the possible effect of seal venting on pin movement is of the order of 5 mils. This could easily be obscured by the shifting base of measurement for pin movement.

Strain measurements on two tie rods and two elements were recorded in the course of each run. The results are tabulated in Table 7, Appendix C. The two tie rod strain measurements agreed with each other within 14 percent. The highest stress recorded was 57,600 psi, which occurred during FFL-9-18g, for a core pressure drop of 130 psi. The variation in measurement from tie rod to tie rod can largely be attributed to the frictional and interlocking forces created by adjacent clusters on the faces and support block of each cluster. Figure 38 shows a force diagram for a typical in-core cluster. From elementary statics we have

$$P \text{ core inlet} + f + w - P \text{ core outlet} = F$$

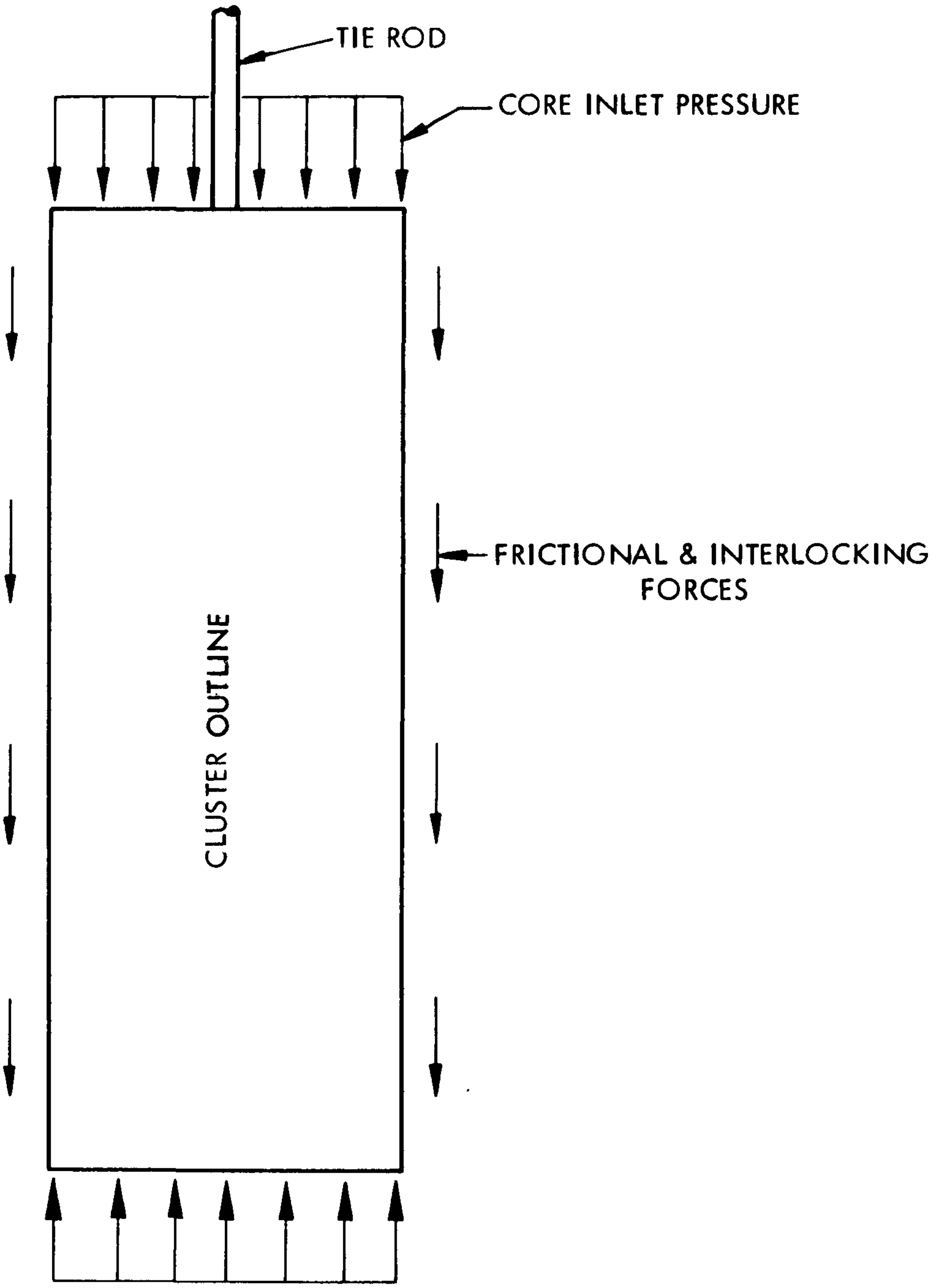


FIGURE 38

FORCE DIAGRAM: IN-CORE CLUSTER

or

$$\Delta P + (f + w) = F$$

where

F = tie rod force

ΔP = force due to core pressure drop

f = frictional and interlocking forces

w = weight of cluster

During calibration, which occurs during a no-flow condition (i.e., $\Delta P = 0$), the strain gauge bridge is balanced. The weight of the cluster and any residual forces due to intercluster friction are deleted. We then effectively have the following force balance, as seen by the strain grid, for the test in question.

$$\Delta P + f - (f_r + w) = F$$

in which f_r represents residual friction forces. The under or overstatement of the tie rod loading is then dependent upon the magnitude and direction of the residual friction forces. In that this varies from cluster to cluster, the variations in tie rod strain measurements are understandable.

Element strain measurements are presented in Table 7, Appendix C. As was the case in the preceding discussions of strain measurements, these strain gauge bridges were of necessity balanced prior to each test, thereby eliminating any residual stresses. This appears to be reflected in the large variation in strain measurements. The largest strain recorded was 334 micro-inches per inch (FFL-9-18g).

5. Dynamic Behavior

Investigation of aeromechanical stability of the NRX-A design under partial and full power leakage flow rates with seal perturbations was a major objective of the Plugged Core Flow Tests. The means used for monitoring parts of the reactor for vibration were as follows:

a. Accelerometers on the core support blocks.

b. High speed motion pictures of the core support blocks.

c. Microphones in the core outlet plenum.

d. Strain gauges on the lateral support springs.

e. Differential pressure transducers on the probes in the seal chambers and core interstices.

f. Strain gauges on the inner reflector.

g. Strain gauges on the tie rods.

h. Strain gauges on the fuel elements.

Close review of all data records produced no evidence of significant vibration or instabilities. The most reliable and sensitive instruments for detecting core instability were the core support block accelerometers and high speed motion pictures. The accelerometer output was recorded on a visicorder with galvanometers having a flat response from 0 - 1000 cycles per second (i. e., there would be no distortion in acceleration measurements for frequencies from 0 to 1000 cycles per second). The smallest detectable vibration by this means was 0. 3 g. High speed motion pictures were projected on a screen to slightly larger than actual size. Of the five different observers of the films, all concluded that no significant movements or sustained vibrations could be discerned. In no test did the accelerometer or other dynamic measurements indicate sustained vibrations.

III. CONCLUSION AND SUMMARY

The Seal Perturbation Series of experiments performed on the ND 20702 reactor (Plugged Core) conclusively demonstrated the overall stability of the NRX-A1 design configurations within the envelope of conditions explored. These conditions were ambient temperature hydrogen flow, at core inlet pressures from 100 to 700 psia, and core pressure drops from 0 to 130 psi. The introduction of varying degrees of seal venting, simulating a decrease in pressure around the core periphery, caused no significant or sustained vibration. Comparison of perturbed and unperturbed operating conditions showed a decrease in core bundling forces due to fluid pressure profiles.

The vented seals appear to increase the severity of fluid outflow observed along the last fifth of the core periphery above that expected for the unperturbed case. In both perturbed and unperturbed operating conditions, core inflow existed along the first four-fifths of the core. Mechanical measurements of stress, strain and movements were comparable to those reported in WANL-TME-792, "Plugged Core Flow Test Report Phase I Tests." Comparison of these measurements between perturbed and unperturbed operating conditions showed no significant deviations or meaningful trends.

BIBLIOGRAPHY

1. WANL-TME-519, "Test Report on Preliminary Vibration Data Based on Two Single Element Test Configurations," P. Cherish, W. L. Jacob. September 20, 1963.

2. WANL-TME-429, "Preliminary Analysis of Oscillations and Aero-Elastic Vibrations in the KIWI B-4A Reactor," C. A. Bodenschatz, E. A. DeZubay, H. L. Morrison. July 1963.

3. WANL-TME-485, "Effects of Lateral Support Abnormalities and Core Inlet Band on the Vibration Characteristics of NRX-A1," P. J. Blake, A. F. Maguire, B. L. Pierce. August 1963.

4. WANL-TME-423, "Analog Computer Study of Leakage Flow Induced Core Vibrations," P. J. Blake. July 1963 and Addendum, September 1963.

5. WANL-TME-645, "Comparisons of Analytical and Experimental Flow Induced Core Vibrations," B. L. Pierce. January 1964

6. WANL-TME-478, "Alternate Methods of Investigating Flow Induced Vibrations," E. A. DeZubay. August 1963.

7. WANL-TME-605, "Phase I Flow Induced Vibration Tests," P. Cherish, R. A. Hindle, J. D. Holmgren, G. J. Leff. December 1963.

8. WANL-TME-656, "Component Test A-11 Phase II Flow Induced Vibration Test," P. Cherish, G. J. Leff. January 1964.

9. WANL-TME-992, "A-11 Phases III and IV Flow Induced Vibration Tests," P. Cherish, G. J. Leff. October 1964.

10. WANL-TME-816, "A-11 Seven Cluster Model Phase V - Flow Induced Vibration Tests," P. Cherish, G. J. Leff. September 1964.

11. WANL-TME-792, "Plugged Core Flow Test Report Phase I Tests," Prerequisite to NRX-A2, Reactor Engineering. September 1964.

12. WANL-TNR-095, "Component Test Program."

13. WANL-TNR-137, "NRX-A Block I Mechanical Design," November 1963.

APPENDIX A

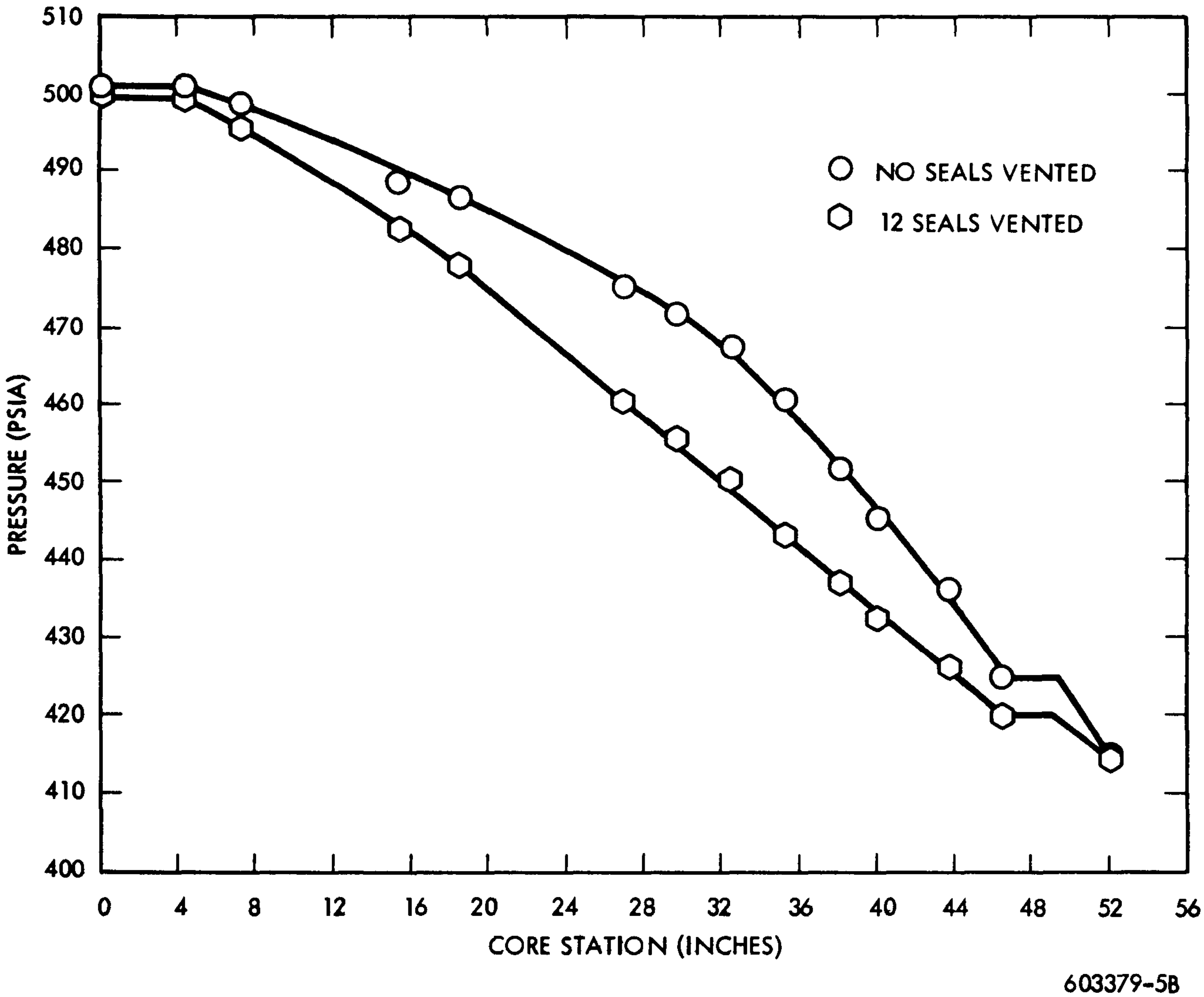


FIGURE 39

SEAL PRESSURE PROFILES - FFL-9-19a, 19d

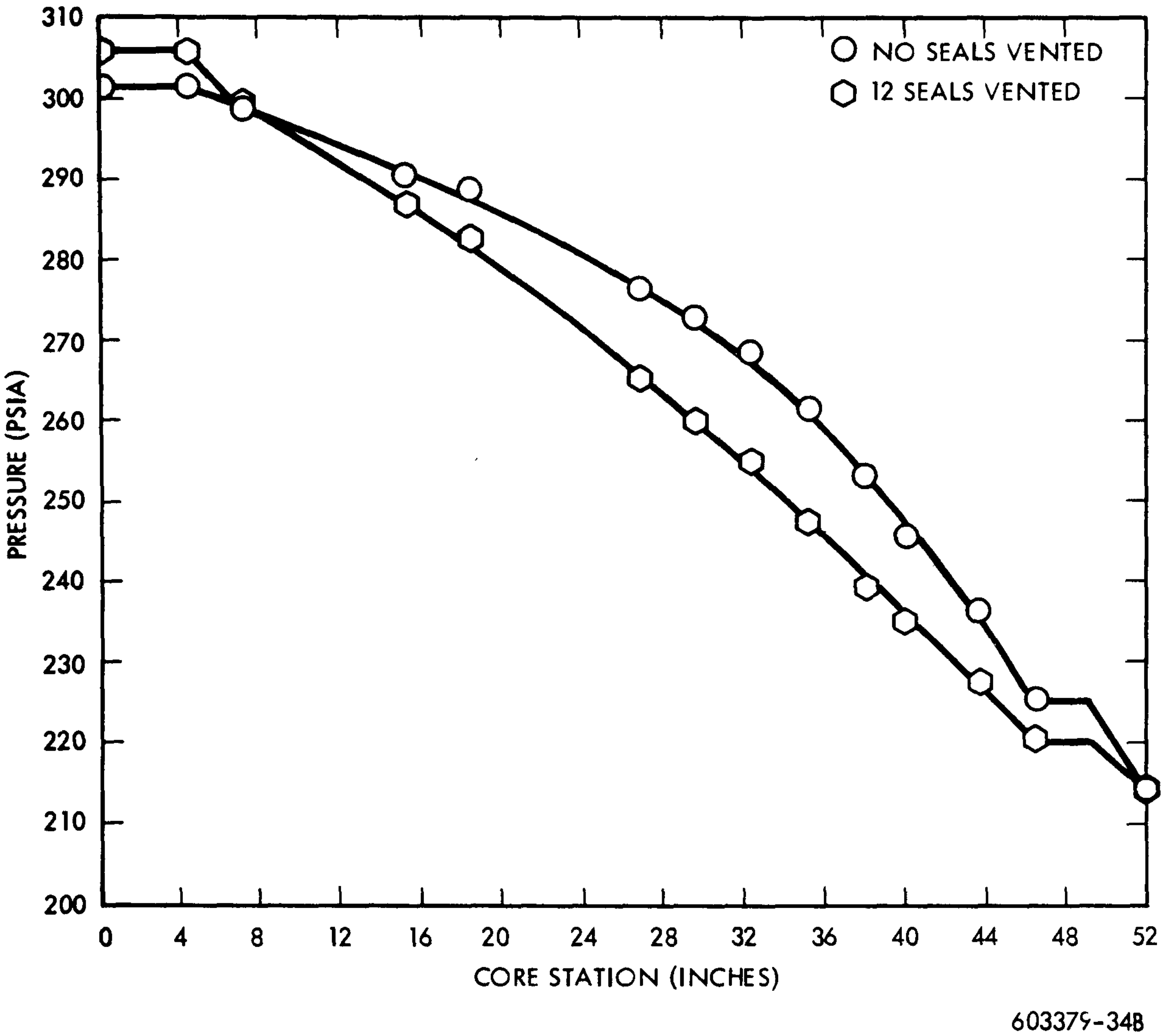


FIGURE 40

SEAL PRESSURE PROFILES - FFL-9-17e, 17h

TABLE 5

SEAL PRESSURE PROFILE DATA

TEST NUMBER		21a	21c	22a	19e	20b	22b	18e	18g	22c	19a	19d	17e	17h
Core Inlet Pressure (psia)		700.0	700.0	700.0	500.0	500.0	500.0	300.0	300.0	300.0	500.0	500.0	300.0	300.0
Core Pressure Drop (psid)		130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	90.0	90.0	90.0	90.0
Number of Seals Vented		None	8	16	None	8	16	None	8	16	None	12	None	12
Seal Designation	Elevation (inches)	Seal Pressure (psia)												
P 703	0.0	699.3	699.3	699.3	492.0	493.4	500.0	296.1	298.6	300.0	501.9	499.7	301.6	306.0
DP 416	4.34	699.3	699.3	699.0	492.0	493.4	500.0	292.6	298.5	300.0	501.9	499.6	301.6	306.0
DP 401	7.16	695.1	699.3	682.9	484.1	489.3	484.0	289.1	294.7	287.6	498.8	495.6	298.6	299.0
DP 409	9.47													
DP 402	12.80													
DP 410	15.60	683.1	677.3	660.9	474.1	476.8	462.0	279.1	282.7	268.6	489.8	482.6	290.6	287.0
DP 403	18.40	677.1	672.3	654.2	470.6	472.3	455.3	275.5	278.2	262.6	487.0	478.0	288.0	282.5
DP 411	21.20													
DP 404	24.00													
DP 412	26.80	660.1	647.3	629.2	455.6	449.3	430.3	260.5	254.7	238.6	475.5	460.0	276.5	265.0
DP 405	29.65	654.8	639.3	622.8	450.6	441.7	423.3	255.5	246.7	231.6	471.7	455.0	272.5	259.8
DP 413	32.50	649.0	631.4	616.3	455.2	434.3	416.7	250.0	238.9	224.8	476.6	450.2	268.5	254.9
DP 406	35.30	639.2	619.4	607.1	436.2	423.3	407.1	240.6	226.9	214.5	460.6	443.1	261.5	247.5
DP 414	38.10	626.8	606.8	597.2	425.2	411.7	397.2	229.6	214.9	204.3	451.5	436.7	253.1	239.6
DP 407	40.90	617.3	598.2	592.2	416.6	403.2	390.4	218.6	204.3	195.3	445.1	432.2	245.7	233.8
DP 415	43.70	604.5	588.2	585.4	404.2	393.7	383.0	205.2	193.2	186.1	436.1	426.2	236.7	227.3
DP 408	46.52	588.5	577.3	578.6	389.2	383.8	376.0	187.8	180.6	176.1	424.9	419.7	225.3	220.3
P 710	54.20	573.3	567.0	573.1	374.2	374.3	369.4	169.3	169.3	167.5	414.2	414.2	214.3	2.413

APPENDIX B

TABLE 6

INTERELEMENT PRESSURE DATA

FFL- 9-18E

CORE INLET PRESSURE (PSIA)=300.0
CORE PRESSURE DROP (PSID)=123.3

CORE INLET TEMPERATURE (F)=83.5
CORE OUTLET TEMPERATURE (F)=92.3

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	296.5	18.00	0.	7.16
DP707	237.5	7.50	285.	7.16
DP766	297.3	17.50	45.	7.16
DP761	223.7	13.50	45.	7.16
DP709	235.0	17.50	285.	7.16
DP706	234.9	7.50	165.	7.16
DP708	296.7	17.50	165.	7.16
DP705	252.8	7.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	282.9	18.00	0.	18.40
DP720	244.5	0.	0.	18.40
DP714	210.1	7.50	45.	18.40
DP730	236.9	7.50	285.	18.40
DP742	282.9	17.50	165.	18.40
DP722	246.0	7.50	165.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	262.9	18.00	45.	29.65
DP743	214.5	0.	0.	29.65
DP763	220.3	13.50	45.	29.65
DP724	198.5	7.50	165.	29.65
DP740	262.3	17.50	45.	29.65
DP751	261.4	17.50	285.	29.65
DP732	199.6	7.50	285.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	226.0	18.00	113.	40.90
DP736	208.6	0.	0.	40.90
DP726	194.8	7.50	165.	40.90
DP746	221.4	17.50	285.	40.90
DP767	226.5	17.50	45.	40.90
DP718	191.7	7.50	45.	40.90
DP738	228.2	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	195.2	18.00	353.	46.52
DP747	214.3	0.	0.	46.52
DP748	203.4	17.50	285.	46.52
DP735	220.4	7.50	285.	46.52
DP737	201.9	17.50	45.	46.52
DP719	221.4	7.50	45.	46.52
DP727	205.3	7.50	165.	46.52
DP765	210.7	13.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-18e

FFL- 9-18F CORE INLET PRESSURE (PSIA)=303.1 CORE INLET TEMPERATURE (F)=83.5
CORE PRESSURE DROP (PSID)=130.8 CORE OUTLET TEMPERATURE (F)=82.3

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	299.7	18.00	0.	7.16
DP708	299.3	17.50	165.	7.16
DP707	240.7	7.50	285.	7.16
DP706	238.1	7.50	165.	7.16
DP709	299.0	17.50	285.	7.16
DP761	226.7	13.50	45.	7.16
DP766	300.8	17.50	45.	7.16
DP705	252.8	7.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	286.1	18.00	165.	18.40
DP730	234.9	7.50	285.	18.40
DP742	285.4	17.50	165.	18.40
DP722	245.4	7.50	165.	18.40
DP714	212.8	7.50	45.	18.40
DP720	243.7	0.	0.	18.40
DP762	279.0	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	262.9	18.00	45.	29.65
DP743	212.7	0.	0.	29.65
DP751	261.0	17.50	285.	29.65
DP763	220.3	13.50	45.	29.65
DP732	199.3	7.50	285.	29.65
DP740	262.0	17.50	45.	29.65
DP724	195.7	7.50	165.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	216.0	18.00	165.	40.90
DP736	205.0	0.	0.	40.90
DP746	216.3	17.50	285.	40.90
DP726	191.9	7.50	165.	40.90
DP767	218.5	17.50	45.	40.90
DP738	217.7	17.50	45.	40.90
DP718	188.2	7.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	186.9	18.00	163.	46.52
DP727	201.0	7.50	165.	46.52
DP719	216.5	7.50	45.	46.52
DP737	194.2	17.50	45.	46.52
DP735	212.3	7.50	285.	46.52
DP748	195.7	17.50	285.	46.52
DP747	205.1	0.	0.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-18f

FFL- 9-18G

CORE INLET PRESSURE (PSIA)=298.6 CORE INLET TEMPERATURE (F)=83.5
CORE PRESSURE DROP (PSID)=129.3 CORE OUTLET TEMPERATURE (F)=82.7

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	294.7	18.00	0.	7.16
DP708	294.9	17.50	165.	7.16
DP707	235.7	7.50	285.	7.16
DP7C6	233.1	7.50	165.	7.16
DP7C9	293.9	17.50	285.	7.16
DP761	221.7	13.50	45.	7.16
DP766	296.0	17.5C	45.	7.16
DP7C5	248.4	7.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	278.2	18.CO	165.	18.40
DP730	232.2	7.50	285.	18.40
DP722	240.6	7.50	165.	18.40
DP742	276.7	17.50	165.	18.40
DP714	204.9	7.50	45.	18.40
DP720	239.8	0.	0.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	246.7	18.00	45.	29.65
DP743	207.8	0.	0.	29.65
DP751	246.1	17.50	285.	29.65
DP763	218.0	13.50	45.	29.65
DP732	183.6	7.50	285.	29.65
DP740	246.6	17.50	45.	29.65
DP724	190.2	7.50	165.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	204.3	18.00	165.	40.90
DP736	199.8	0.	0.	40.90
DP746	205.0	17.50	285.	40.90
DP726	187.6	7.50	165.	40.90
DP767	206.8	17.50	45.	40.90
DP738	205.6	17.50	45.	40.90
DP718	184.5	7.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	180.6	18.00	353.	46.52
DP727	196.2	7.50	165.	46.52
DP719	208.9	7.50	45.	46.52
DP737	187.7	17.50	45.	46.52
DP735	204.6	7.50	285.	46.52
DP748	188.7	17.50	285.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-18g

FFL- 9-18H

CORE INLET PRESSURE (PSIA)=301.8
CORE PRESSURE DROP (PSID)=129.7

CORE INLET TEMPERATURE (F)=81.5
CORE OUTLET TEMPERATURE (F)=79.2

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	297.4	18.00	0.	7.16
DP708	297.6	17.50	165.	7.16
DP707	238.4	7.50	285.	7.16
DP706	235.8	7.50	165.	7.16
DP709	296.5	17.50	285.	7.16
DP761	224.4	13.50	45.	7.16
DP766	299.2	17.50	45.	7.16
DP705	253.1	7.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	273.4	18.00	165.	18.40
DP730	232.0	7.50	285.	18.40
DP742	271.6	17.50	165.	18.40
DP722	242.1	7.50	165.	18.40
DP714	205.9	7.50	45.	18.40
DP720	241.6	0.	0.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	241.2	18.00	45.	29.65
DP743	209.9	0.	0.	29.65
DP751	240.9	17.50	285.	29.65
DP763	240.5	13.50	45.	29.65
DP732	179.5	7.50	285.	29.65
DP740	241.3	17.50	45.	29.65
DP724	193.0	7.50	165.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	203.2	18.00	165.	40.90
DP736	201.3	0.	0.	40.90
DP746	203.9	17.50	285.	40.90
DP726	190.4	7.50	165.	40.90
DP767	205.6	17.50	45.	40.90
DP738	205.3	17.50	45.	40.90
DP718	187.4	7.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	182.2	18.00	163.	46.52
DP727	197.8	7.50	165.	46.52
DP719	209.8	7.50	45.	46.52
DP737	189.0	17.50	45.	46.52
DP735	205.7	7.50	285.	46.52
DP748	190.0	17.50	285.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-18h

FFL- 9-19E CORE INLET PRESSURE (PSIA)=492.0 CORE INLET TEMPERATURE (F)=87.6
CORE PRESSURE DROP (PSID)=117.8 CORE OUTLET TEMPERATURE (F)=85.5

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	484.1	18.00	45.	7.16
DP704	440.7	0.	0.	7.16
DP7C6	430.5	7.50	165.	7.16
DP708	484.2	17.50	165.	7.16
DP707	424.9	7.50	285.	7.16
DP709	483.4	17.50	285.	7.16
DP766	485.6	17.50	45.	7.16
DP761	419.1	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	470.6	18.00	165.	18.40
DP762	444.9	13.50	45.	18.40
DP714	405.2	7.50	45.	18.40
DP720	435.6	0.	0.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	450.6	18.00	285.	29.65
DP751	449.4	17.50	285.	29.65
DP763	390.1	13.50	45.	29.65
DP724	393.7	7.50	165.	29.65
DP732	386.4	7.50	285.	29.65
DP743	406.4	0.	0.	29.65
DP740	450.2	17.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	416.6	18.00	0.	40.90
DP736	400.5	0.	0.	40.90
DP726	390.0	7.50	165.	40.90
DP767	417.3	17.50	45.	40.90
DP718	387.7	7.50	45.	40.90
DP746	415.5	17.50	285.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	389.2	18.00	0.	46.52
DP765	402.3	13.50	45.	46.52
DP727	397.5	7.50	165.	46.52
DP735	410.9	7.50	285.	46.52
DP737	395.1	17.50	45.	46.52
DP748	396.4	17.50	285.	46.52
DP719	409.4	7.50	45.	46.52
DP747	402.6	0.	0.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-19e

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

Astronuclear Laboratory

FFL-9-19F

CORE INLET PRESSURE (PSIA)=500.6 CORE INLET TEMPERATURE (F)=87.6
CORE PRESSURE DROP (PSID)=126.4 CORE OUTLET TEMPERATURE (F)=85.5

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	496.5	18.00	45.	7.16
DP704	447.0	0.	0.	7.16
DP706	442.0	7.50	165.	7.16
DP708	496.6	17.50	165.	7.16
DP707	437.3	7.50	285.	7.16
DP709	495.6	17.50	285.	7.16
DP766	482.9	17.50	45.	7.16
DP761	431.5	13.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	481.6	18.00	165.	18.40
DP762	455.9	13.50	45.	18.40
DP714	415.9	7.50	45.	18.40
DP720	442.7	0.	0.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	457.8	18.00	285.	29.65
DP751	456.1	17.50	285.	29.65
DP763	391.6	13.50	45.	29.65
DP724	394.5	7.50	165.	29.65
DP732	381.7	7.50	285.	29.65
DP743	412.1	0.	0.	29.65
DP740	457.2	17.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	412.3	18.00	0.	40.90
DP736	400.8	0.	0.	40.90
DP726	389.9	7.50	165.	40.90
DP718	387.4	7.50	45.	40.90
DP746	412.5	17.50	285.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	386.3	18.00	285.	46.52
DP765	370.2	13.50	45.	46.52
DP727	398.1	7.50	165.	46.52
DP735	409.0	7.50	285.	46.52
DP737	392.8	17.50	45.	46.52
DP748	394.0	17.50	285.	46.52
DP719	410.4	7.50	45.	46.52
DP747	392.6	0.	0.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-19f

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act 1954~~

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

Astronuclear Laboratory

WANL-TME-1207

FFL- 9-20A

CORE INLET PRESSURE (PSIA)=694.6 CORE INLET TEMPERATURE (F)=67.9
CORE PRESSURE DROP (PSID)=123.0 CORE OUTLET TEMPERATURE (F)=66.6

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	690.1	18.00	285.	7.16
DP761	624.8	13.50	45.	7.16
DP709	689.1	17.50	285.	7.16
DP766	691.7	17.50	45.	7.16
DP704	638.8	0.	0.	7.16
DP707	632.9	7.50	285.	7.16
DP708	690.2	17.50	165.	7.16
DP706	636.6	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	674.1	18.00	113.	18.40
DP742	673.1	17.50	165.	18.40
DP714	608.6	7.50	45.	18.40
DP720	632.1	0.	0.	18.40
DP730	617.2	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	652.3	18.00	97.	29.65
DP751	651.6	17.50	285.	29.65
DP740	651.5	17.50	45.	29.65
DP724	587.5	7.50	165.	29.65
DP732	587.8	7.50	285.	29.65
DP743	600.8	0.	0.	29.65
DP763	585.3	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	614.8	18.00	165.	40.90
DP718	582.0	7.50	45.	40.90
DP736	601.1	0.	0.	40.90
DP726	585.4	7.50	165.	40.90
DP767	615.4	17.50	45.	40.90
DP746	613.4	17.50	285.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	586.7	18.00	277.	46.52
DP737	593.0	17.50	45.	46.52
DP748	594.1	17.50	285.	46.52
DP727	596.2	7.50	165.	46.52
DP735	609.0	7.50	285.	46.52
DP765	594.6	13.50	45.	46.52
DP747	590.7	0.	0.	46.52
DP719	611.5	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-20a

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~
~~Atomic Energy Act - 1954~~

[redacted]

Astronuclear Laboratory

WANL-TME-1207

FFL- 9-20B

CORE INLET PRESSURE (PSIA)=493.4 CORE INLET TEMPERATURE (F)=69.5
CORE PRESSURE DROP (PSID)=119.1 CORE OUTLET TEMPERATURE (F)=61.3

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	489.3	18.00	285.	7.16
DP761	423.8	13.50	45.	7.16
DP709	488.4	17.50	285.	7.16
DP766	490.8	17.50	45.	7.16
DP704	441.5	0.	0.	7.16
DP707	432.1	7.50	285.	7.16
DP708	489.5	17.50	165.	7.16
DP706	435.9	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	472.3	18.00	113.	18.40
DP742	470.2	17.50	165.	18.40
DP714	406.8	7.50	45.	18.40
DP720	436.1	0.	0.	18.40
DP730	422.3	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	441.7	18.00	97.	29.65
DP751	441.1	17.50	285.	29.65
DP740	441.4	17.50	45.	29.65
DP724	390.4	7.50	165.	29.65
DP732	378.9	7.50	285.	29.65
DP743	404.4	0.	0.	29.65
DP763	385.9	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	403.2	18.00	165.	40.90
DP718	386.5	7.50	45.	40.90
DP736	398.1	0.	0.	40.90
DP726	388.7	7.50	165.	40.90
DP767	405.9	17.50	45.	40.90
DP746	403.8	17.50	285.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	383.8	18.00	277.	46.52
DP737	390.0	17.50	45.	46.52
DP748	391.0	17.50	285.	46.52
DP727	398.5	7.50	165.	46.52
DP735	408.4	7.50	285.	46.52
DP765	387.5	13.50	45.	46.52
DP747	392.8	0.	0.	46.52
DP719	411.3	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-20b

[redacted]

FFL- 9-20C

CORE INLET PRESSURE (PSIA)=491.2
CORE PRESSURE DROP (PSID)=116.9
CORE INLET TEMPERATURE (F)=65.5
CORE OUTLET TEMPERATURE (F)=62.8

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	486.2	18.00	285.	7.16
DP761	420.9	13.50	45.	7.16
DP709	485.2	17.50	285.	7.16
DP766	488.2	17.50	45.	7.16
DP704	441.1	0.	0.	7.16
DP707	428.8	7.50	285.	7.16
DP708	486.4	17.5C	165.	7.16
DP7C6	432.7	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	462.2	18.00	113.	18.40
DP742	460.2	17.50	165.	18.40
DP714	401.4	7.50	45.	18.40
DP720	434.5	0.	0.	18.40
DP73C	418.4	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	432.6	18.00	97.	29.65
DP751	432.3	17.50	285.	29.65
DP740	432.5	17.50	45.	29.65
DP724	389.9	7.50	165.	29.65
DP732	377.4	7.50	285.	29.65
DP743	403.6	0.	0.	29.65
DP763	384.2	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	399.3	18.C0	165.	40.90
DP718	386.4	7.50	45.	40.90
DP736	396.8	0.	0.	40.90
DP726	388.5	7.50	165.	40.90
DP767	402.0	17.50	45.	40.90
DP746	400.0	17.50	285.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	381.9	18.00	277.	46.52
DP737	387.7	17.50	45.	46.52
DP748	388.7	17.50	285.	46.52
DP727	396.9	7.50	165.	46.52
DP735	407.0	7.50	285.	46.52
DP765	385.6	13.50	45.	46.52
DP747	390.5	C.	0.	46.52
DP719	408.8	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-20c

FFL- 9-20D

CORE INLET PRESSURE (PSIA)=655.0
CORE PRESSURE DROP (PSID)= 95.1
CORE INLET TEMPERATURE (F)=67.1
CORE OUTLET TEMPERATURE (F)=63.6

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	652.4	18.00	285.	7.16
DP761	587.1	13.50	45.	7.16
DP709	651.7	17.50	285.	7.16
DP766	653.9	17.50	45.	7.16
DP704	608.1	0.	0.	7.16
DP707	595.2	7.50	285.	7.16
DP708	652.6	17.50	165.	7.16
DP706	598.9	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	640.4	18.00	113.	18.40
DP742	639.8	17.50	165.	18.40
DP714	553.3	7.50	45.	18.40
DP720	533.7	0.	0.	18.40
DP730	589.7	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	623.8	18.00	97.	29.65
DP751	622.4	17.50	285.	29.65
DP740	623.0	17.50	45.	29.65
DP724	570.5	7.50	165.	29.65
DP732	563.5	7.50	285.	29.65
DP743	618.5	0.	0.	29.65
DP763	617.7	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	590.3	18.00	165.	40.90
DP718	570.4	7.50	45.	40.90
DP736	581.1	0.	0.	40.90
DP726	573.1	7.50	165.	40.90
DP767	592.1	17.50	45.	40.90
DP746	591.0	17.50	285.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	572.8	18.00	277.	46.52
DP737	578.1	17.50	45.	46.52
DP748	578.0	17.50	285.	46.52
DP727	581.7	7.50	165.	46.52
DP735	587.6	7.50	285.	46.52
DP765	580.1	13.50	45.	46.52
DP747	577.6	0.	0.	46.52
DP719	587.8	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-20d

FFL- 9-21A

CORE INLET PRESSURE (PSIA)=699.3 CORE INLET TEMPERATURE (F)=93.2
CORE PRESSURE DROP (PSID)=126.0 CORE OUTLET TEMPERATURE (F)=86.6

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	695.1	18.00	293.	7.16
DP704	644.2	0.	0.	7.16
DP705	644.9	7.50	45.	7.16
DP7C6	641.3	7.50	165.	7.16
DP707	636.4	7.50	285.	7.16
DP708	680.2	17.50	165.	7.16
DP709	694.3	17.50	285.	7.16
DP761	628.7	13.50	45.	7.16
DP766	696.6	17.50	45.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	677.1	18.00	113.	18.40
DP714	610.4	7.50	45.	18.40
DP720	640.2	0.	0.	18.40
DP762	664.3	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	654.8	18.00	353.	29.65
DP724	590.5	7.50	165.	29.65
DP732	589.3	7.50	285.	29.65
DP740	654.5	17.50	45.	29.65
DP743	602.4	0.	0.	29.65
DP751	653.6	17.50	285.	29.65
DP763	647.8	13.50	45.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	617.3	18.00	165.	40.90
DP718	579.2	7.50	45.	40.90
DP726	587.5	7.50	165.	40.90
DP736	602.6	0.	0.	40.90
DP746	615.8	17.50	285.	40.90
DP767	618.1	17.50	45.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	588.5	18.00	165.	46.52
DP719	610.4	7.50	45.	46.52
DP727	597.4	7.50	165.	46.52
DP735	609.4	7.50	285.	46.52
DP737	595.1	17.50	45.	46.52
DP748	596.0	17.50	285.	46.52
DP765	599.4	13.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-21a

[redacted]

FFL- 9-21B

CORE INLET PRESSURE (PSIA)=699.3 CORE INLET TEMPERATURE (F)=91.0
CORE PRESSURE DROP (PSID)=130.2 CORE OUTLET TEMPERATURE (F)=86.6

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	691.3	18.00	163.	7.16
DP766	692.5	17.50	45.	7.16
DP704	637.6	0.	0.	7.16
DP705	638.4	7.50	45.	7.16
DP708	676.4	17.50	165.	7.16
DP709	690.4	17.50	285.	7.16
DP761	624.9	13.50	45.	7.16
DP707	632.6	7.50	285.	7.16
DP706	637.5	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	675.3	18.00	293.	18.40
DP742	674.1	17.50	165.	18.40
DP762	662.6	13.50	45.	18.40
DP720	637.1	0.	0.	18.40
DP714	608.6	7.50	45.	18.40
DP730	614.4	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	651.9	18.00	45.	29.65
DP724	586.1	7.50	165.	29.65
DP751	650.2	17.50	285.	29.65
DP740	651.2	17.50	45.	29.65
DP732	586.2	7.50	285.	29.65
DP763	585.9	13.50	45.	29.65
DP743	597.7	0.	0.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	606.1	18.00	7.	40.90
DP718	576.0	7.50	45.	40.90
DP726	583.2	7.50	165.	40.90
DP767	608.8	17.50	45.	40.90
DP746	606.1	17.50	285.	40.90
DP736	593.3	0.	0.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	580.7	18.00	73.	46.52
DP737	587.6	17.50	45.	46.52
DP748	588.5	17.50	285.	46.52
DP735	604.3	7.50	285.	46.52
DP727	592.5	7.50	165.	46.52
DP719	605.3	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-21b

[redacted]

FFL- 9-21C

CORE INLET PRESSURE (PSIA)=699.3
CORE PRESSURE DROP (PSID)=131.5
CORE INLET TEMPERATURE (F)=91.0
CORE OUTLET TEMPERATURE (F)=85.4

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	690.3	18.00	163.	7.16
DP766	691.8	17.50	45.	7.16
DP704	637.2	0.	0.	7.16
DP705	637.4	7.50	45.	7.16
DP708	675.4	17.50	165.	7.16
DP709	689.4	17.50	285.	7.16
DP761	623.9	13.50	45.	7.16
DP707	631.6	7.50	285.	7.16
DP706	636.5	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	672.3	18.00	293.	18.40
DP742	669.9	17.50	165.	18.40
DP762	659.5	13.50	45.	18.40
DP720	638.9	0.	0.	18.40
DP714	605.6	7.50	45.	18.40
DP730	614.2	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	639.3	18.00	45.	29.65
DP724	583.7	7.50	165.	29.65
DP751	638.8	17.50	285.	29.65
DP740	639.5	17.50	45.	29.65
DP732	574.4	7.50	285.	29.65
DP763	582.5	13.50	45.	29.65
DP743	596.9	0.	0.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	598.2	18.00	7.	40.90
DP718	576.4	7.50	45.	40.90
DP726	614.4	7.50	165.	40.90
DP767	601.2	17.50	45.	40.90
DP746	598.5	17.50	285.	40.90
DP736	591.2	0.	0.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	577.3	18.00	73.	46.52
DP737	583.8	17.50	45.	46.52
DP748	584.5	17.50	285.	46.52
DP735	601.4	7.50	285.	46.52
DP727	590.5	7.50	165.	46.52
DP719	601.6	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-21c

[redacted]

Astronuclear Laboratory

WANL-TME-1207

FFL- 9-21D

CORE INLET PRESSURE (PSIA)=699.3 CORE INLET TEMPERATURE (F)=91.0
CORE PRESSURE DROP (PSID)=129.4 CORE OUTLET TEMPERATURE (F)=84.4

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	687.9	18.00	163.	7.16
DP766	689.9	17.50	45.	7.16
DP704	638.9	0.	0.	7.16
DP705	639.2	7.50	45.	7.16
DP708	673.0	17.50	165.	7.16
DP709	686.7	17.50	285.	7.16
DP761	621.5	13.50	45.	7.16
DP707	629.2	7.50	285.	7.16
DP706	634.1	7.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	662.5	18.00	293.	18.40
DP742	661.3	17.50	165.	18.40
DP762	649.7	13.50	45.	18.40
DP720	636.2	0.	0.	18.40
DP714	598.1	7.50	45.	18.40
DP730	621.5	7.50	285.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	630.5	18.00	45.	29.65
DP724	585.4	7.50	165.	29.65
DP751	630.3	17.50	285.	29.65
DP740	630.7	17.50	45.	29.65
DP732	574.6	7.50	285.	29.65
DP763	583.5	13.50	45.	29.65
DP743	597.8	0.	0.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	595.6	18.00	7.	40.90
DP718	578.7	7.50	45.	40.90
DP726	607.5	7.50	165.	40.90
DP767	598.4	17.50	45.	40.90
DP746	595.9	17.50	285.	40.90
DP736	591.7	0.	0.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	578.1	18.00	73.	46.52
DP737	584.3	17.50	45.	46.52
DP748	584.8	17.50	285.	46.52
DP735	600.7	7.50	285.	46.52
DP727	591.1	7.50	165.	46.52
DP719	600.5	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-21d

[redacted]

[redacted]

FFL- 9-22A   CORE INLET PRESSURE (PSIA)=699.3   CORE INLET TEMPERATURE (F)=80.4
CORE PRESSURE DROP (PSID)=126.2   CORE OUTLET TEMPERATURE (F)=56.3

CORE RADIAL PROFILE   ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	682.9	18.00	187.	7.16
DP706	620.6	7.50	165.	7.16
DP705	634.2	7.50	45.	7.16
DP704	635.2	0.	0.	7.16
DP766	686.7	17.50	45.	7.16
DP709	681.9	17.50	285.	7.16
DP761	610.1	13.50	45.	7.16
DP707	623.3	7.50	285.	7.16
DP708	683.0	17.50	165.	7.16

CORE RADIAL PROFILE   ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	654.2	18.00	7.	18.40
DP742	652.3	17.50	165.	18.40
DP722	622.4	7.50	165.	18.40
DP720	633.5	0.	0.	18.40
DP714	595.5	7.50	45.	18.40
DP730	613.5	7.50	285.	18.40
DP762	639.6	13.50	45.	18.40

CORE RADIAL PROFILE   ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	622.8	18.00	0.	29.65
DP740	623.2	17.50	45.	29.65
DP751	622.9	17.50	285.	29.65
DP763	582.6	13.50	45.	29.65
DP724	584.2	7.50	165.	29.65
DP743	596.5	0.	0.	29.65

CORE RADIAL PROFILE   ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	592.2	18.00	307.	40.90
DP736	593.0	0.	0.	40.90
DP746	593.0	17.50	285.	40.90
DP767	576.5	17.50	45.	40.90
DP718	583.3	7.50	45.	40.90
DP726	599.5	7.50	165.	40.90

CORE RADIAL PROFILE   ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	578.6	18.00	45.	46.52
DP747	596.4	0.	0.	46.52
DP737	584.7	17.50	45.	46.52
DP765	576.9	13.50	45.	46.52
DP748	585.3	17.50	285.	46.52
DP727	593.8	7.50	165.	46.52
DP735	602.3	7.50	285.	46.52
DP719	601.7	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-22a

[redacted]

FFL- 9-228 CORE INLET PRESSURE (PSIA)=500.0 CORE INLET TEMPERATURE (F)=74.4
CORE PRESSURE DROP (PSID)=130.6 CORE OUTLET TEMPERATURE (F)=45.0

CORE RADIAL PROFILE ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	484.0	18.00	187.	7.16
DP706	421.5	7.50	165.	7.16
DP705	436.5	7.50	45.	7.16
DP704	436.8	0.	0.	7.16
DP766	487.6	17.50	45.	7.16
DP709	483.1	17.50	285.	7.16
DP761	411.2	13.50	45.	7.16
DP707	424.4	7.50	285.	7.16
DP708	484.0	17.50	165.	7.16

CORE RADIAL PROFILE ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	455.3	18.00	7.	18.40
DP742	453.1	17.50	165.	18.40
DP722	427.6	7.50	165.	18.40
DP720	436.3	0.	0.	18.40
DP714	395.4	7.50	45.	18.40
DP730	416.7	7.50	285.	18.40
DP762	440.7	13.50	45.	18.40

CORE RADIAL PROFILE ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	423.3	18.00	0.	29.65
DP740	423.7	17.50	45.	29.65
DP751	423.3	17.50	285.	29.65
DP763	381.7	13.50	45.	29.65
DP724	384.1	7.50	165.	29.65
DP743	397.5	0.	0.	29.65

CORE RADIAL PROFILE ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	390.4	18.00	307.	40.90
DP736	392.0	0.	0.	40.90
DP746	391.5	17.50	285.	40.90
DP767	374.2	17.50	45.	40.90
DP718	381.3	7.50	45.	40.90
DP726	397.7	7.50	165.	40.90

CORE RADIAL PROFILE ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	376.0	18.00	45.	46.52
DP747	397.5	0.	0.	46.52
DP737	382.3	17.50	45.	46.52
DP765	374.4	13.50	45.	46.52
DP748	383.0	17.50	285.	46.52
DP727	392.5	7.50	165.	46.52
DP735	400.2	7.50	285.	46.52
DP719	401.2	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-22b

FFL-9-22C   CORE INLET PRESSURE (PSIA)=300.0   CORE INLET TEMPERATURE (F)=74.4
CORE PRESSURE DROP (PSID)=132.5   CORE OUTLET TEMPERATURE (F)=41.5

CORE RADIAL PROFILE   ELEVATION 7.16

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP401	287.6	18.00	187.	7.16
DP706	225.1	7.50	165.	7.16
DP705	244.8	7.50	45.	7.16
DP766	290.3	17.50	45.	7.16
DP704	245.4	0.	0.	7.16
DP709	286.9	17.50	285.	7.16
DP761	221.1	13.50	45.	7.16
DP707	228.0	7.50	285.	7.16
DP708	287.6	17.50	165.	7.16

CORE RADIAL PROFILE   ELEVATION 18.40

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP403	262.6	18.00	7.	18.40
DP742	261.2	17.50	165.	18.40
DP722	234.9	7.50	165.	18.40
DP720	242.7	0.	0.	18.40
DP714	197.7	7.50	45.	18.40
DP730	224.0	7.50	285.	18.40
DP762	248.0	13.50	45.	18.40

CORE RADIAL PROFILE   ELEVATION 29.65

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP405	231.6	18.00	0.	29.65
DP740	231.9	17.50	45.	29.65
DP751	231.1	17.50	285.	29.65
DP763	184.4	13.50	45.	29.65
DP724	186.5	7.50	165.	29.65
DP743	201.6	0.	0.	29.65

CORE RADIAL PROFILE   ELEVATION 40.90

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP407	195.3	18.00	307.	40.90
DP736	195.7	0.	0.	40.90
DP746	196.3	17.50	285.	40.90
DP767	177.6	17.50	45.	40.90
DP718	182.6	7.50	45.	40.90
DP726	205.7	7.50	165.	40.90

CORE RADIAL PROFILE   ELEVATION 46.52

SENSOR DESIGNATION	CORE PRESSURE	RADIUS	ANGULAR LOCATION	ELEVATION
DP408	176.1	18.00	45.	46.52
DP747	201.0	0.	0.	46.52
DP737	183.0	17.50	45.	46.52
DP765	174.5	13.50	45.	46.52
DP748	184.0	17.50	285.	46.52
DP727	194.1	7.50	165.	46.52
DP735	201.0	7.50	285.	46.52
DP719	204.9	7.50	45.	46.52

CORE INTERELEMENT PRESSURES - FFL-9-22c

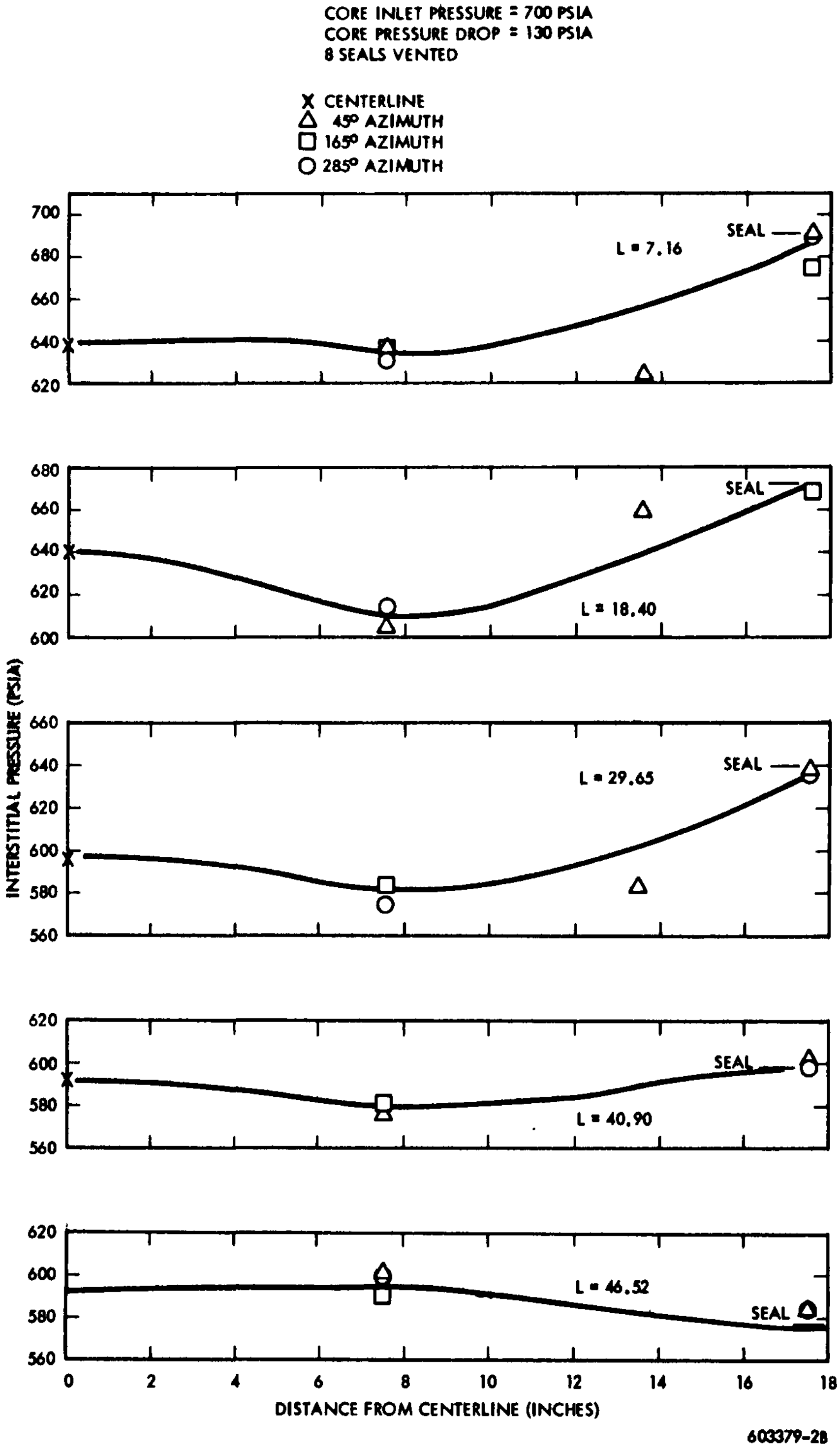


FIGURE 41

CORE INTERELEMENT PRESSURES - FFL-9-21c

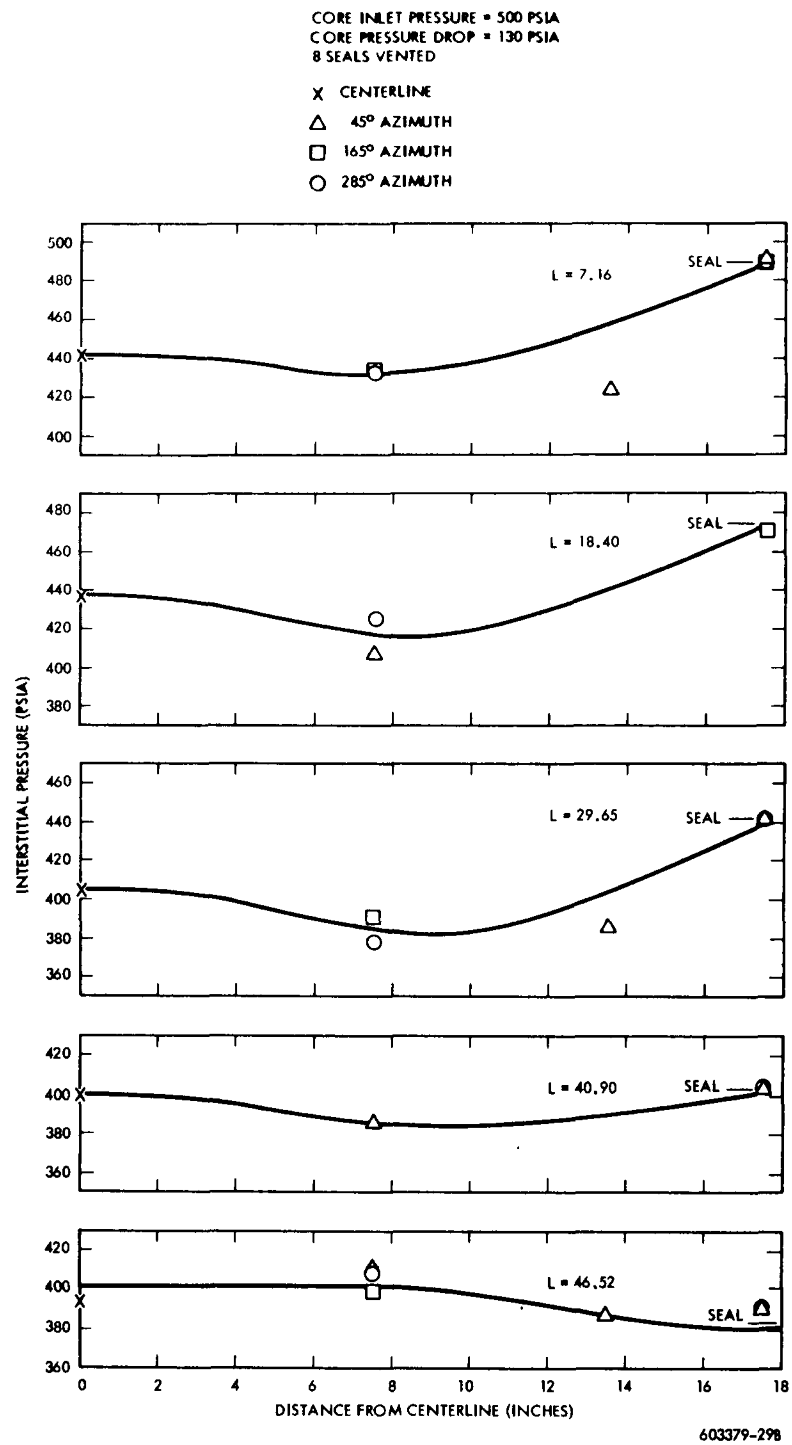


FIGURE 42

CORE INTERELEMENT PRESSURES - FFL-9-20b

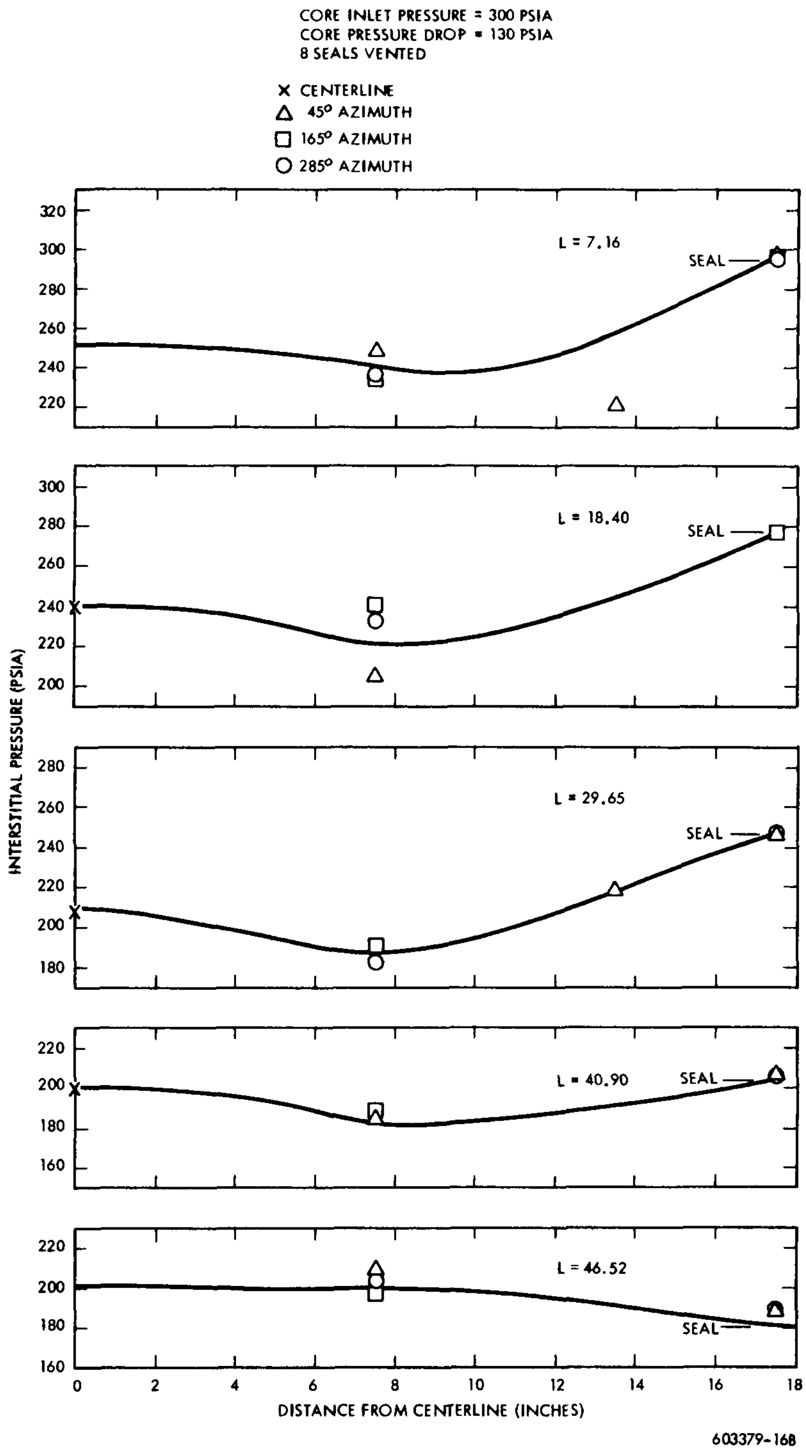


FIGURE 43

CORE INTERELEMENT PRESSURES - FFL-9-18g

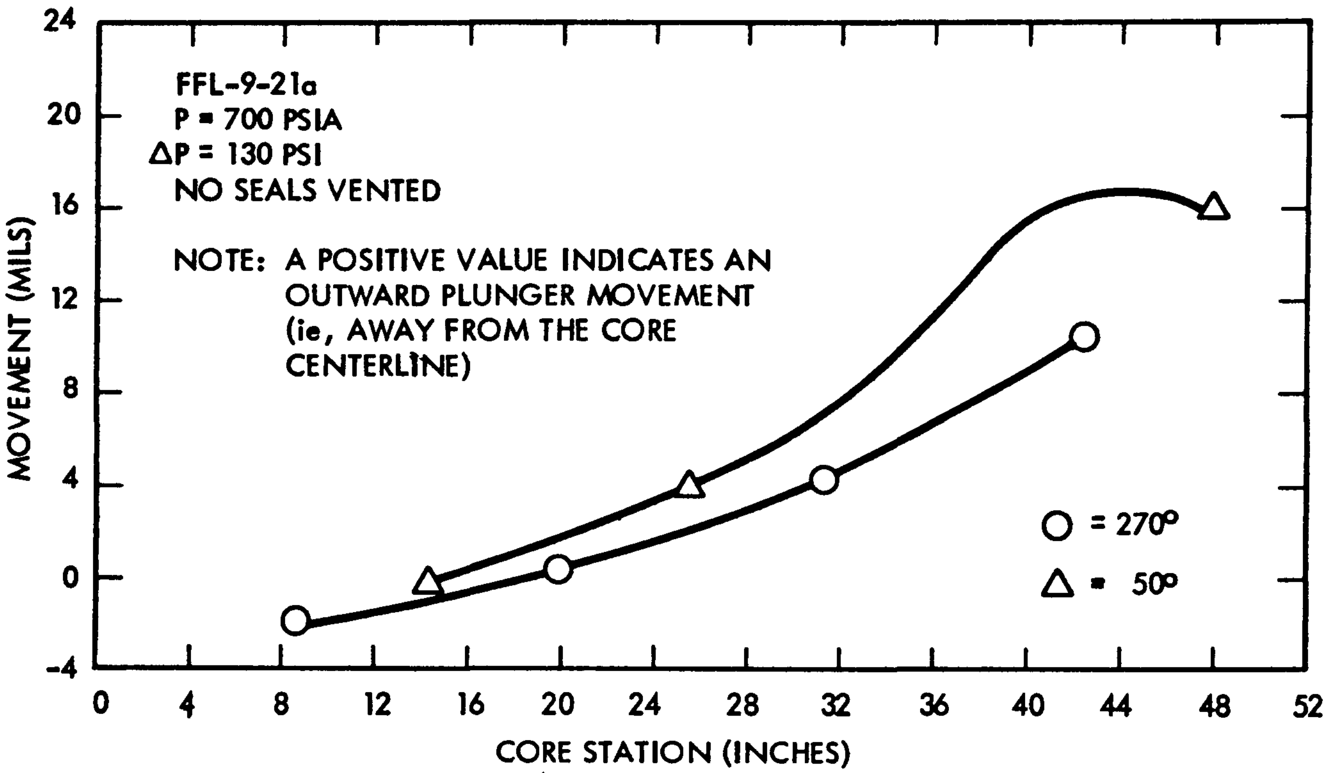
APPENDIX C

TABLE 7

MECHANICAL DATA

TEST DESIGNATION	21a	21c	22a	19e	20b	22b	18e	18g	22c
Core Inlet Pressure	700	700	700	500	500	500	300	300	300
Core Pressure Drop	130	130	130	130	130	130	130	130	130
Number of Seals Vented	0	8	16	0	8	16	0	8	16
Element Strain Data (micro-inches/inch)									
S 726			- 66.91	- 126.67	- 29.73	- 6.69	-252.68	- 279.28	- 66.91
S 774			- 70.07	- 90.73	- 31.67	- 21.02	- 321.24	- 334.22	- 21.02
Tie Rod Strain Data (micro-inches/inch)									
S 763			1500.91	1692.57	1411.18	1543.19	1713.9	1836.08	1500.91
S 768	1254.26	1304.94	1372.36	1640.30	1309.38	1343.76	1640.3	1755.19	1331.20
Pin Movement (mils)									
S 443	- 1.9	- 2.8	- 0.7	- 2.0	- 2.5	- 0.7	- 2.6	- 2.6	0.7
S 444	0.5	0.5	3.1	- 0.5	0.8	4.6	- 1.8	- 0.8	2.1
S 445	4.3	4.3	6.2	- 0.0	5.0	7.2	2.4	5.3	6.2
S 446	10.6	12.4	9.1	6.1	13.5	7.2	3.6	6.0	5.3
S 447	- 0.2	- 0.2	0.4	- 2.7	- 0.8	0.4	- 0.6	- 0.2	- 0.0
S 448	4.0	4.5	5.9	7.6	5.4	6.8	2.0	4.3	6.3
S 450	16.0	19.2	18.5	14.6	20.1	19.8	14.8	18.7	19.2

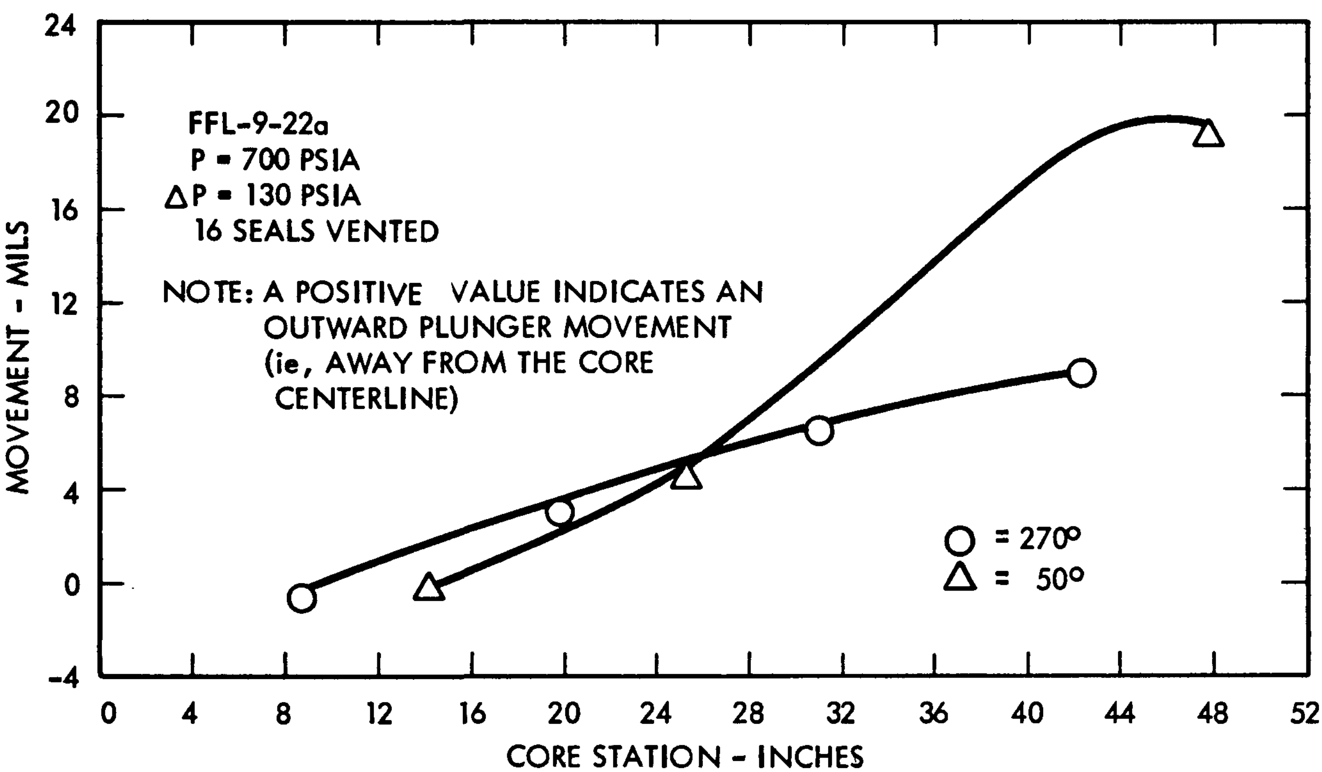
CONFIDENTIAL
RESTRICTED DATA
Atomic Energy Act - 1954



603379-13B

FIGURE 44

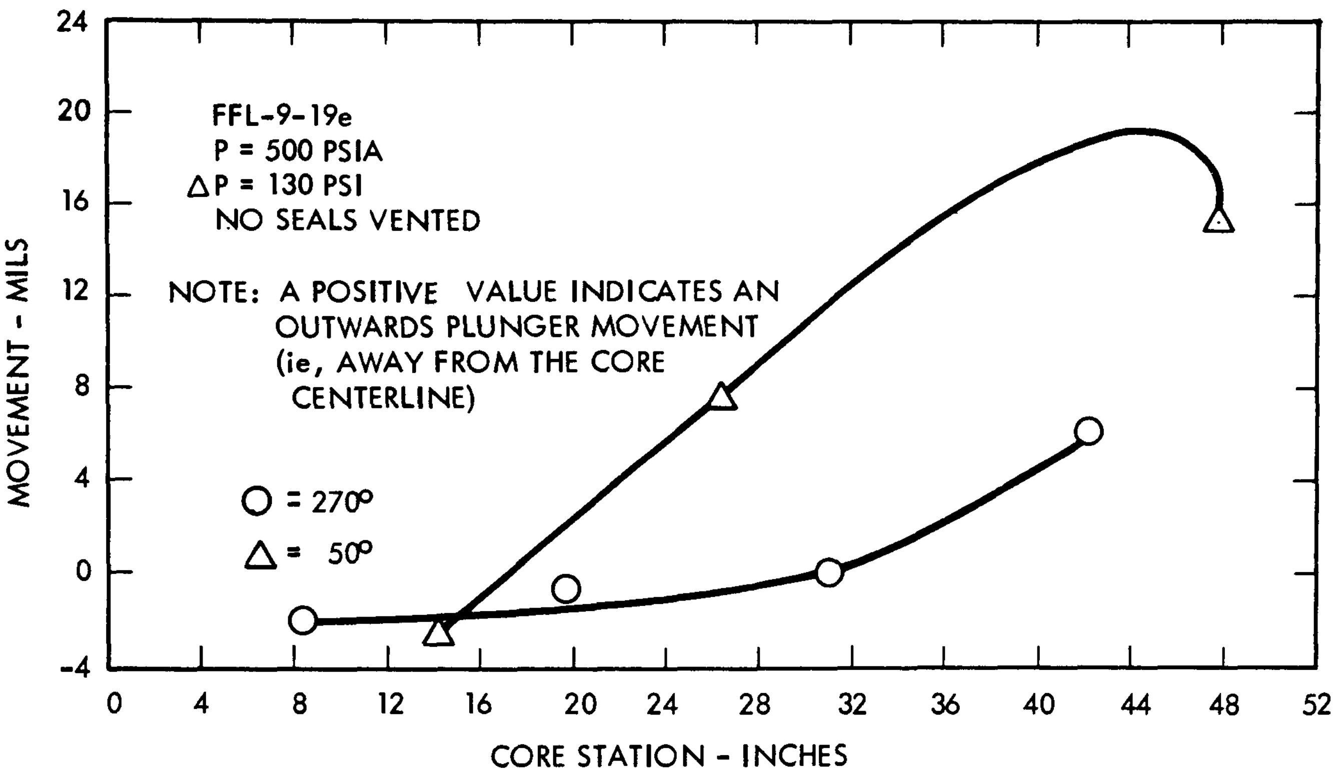
APPARENT PLUNGER PIN MOVEMENT - FFL-9-21a



603379-19B

FIGURE 45

APPARENT PLUNGER PIN MOVEMENT - FFL-9-22a



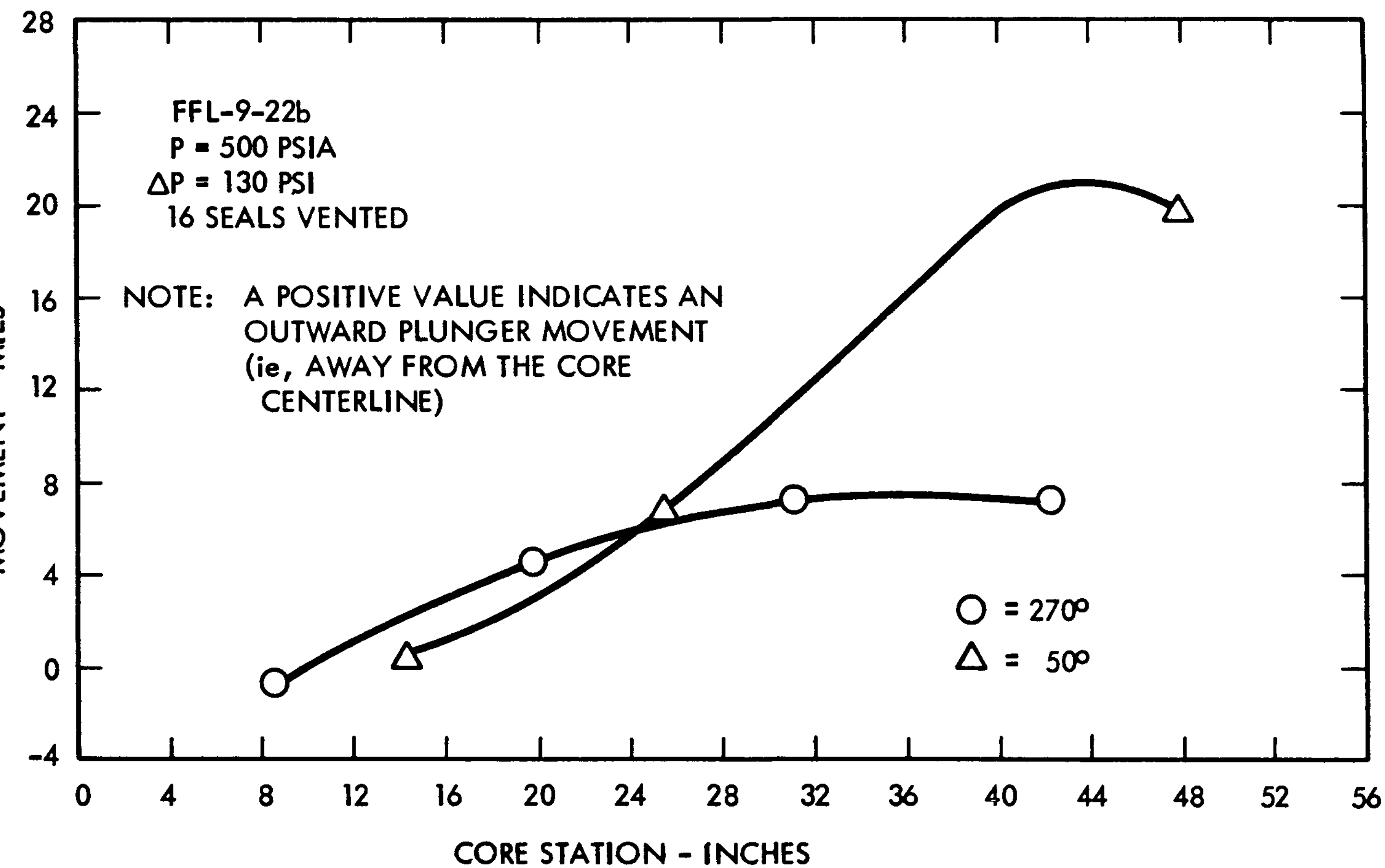
603379-17B

FIGURE 46

APPARENT PLUNGER PIN MOVEMENT - FFL-9-19e

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

Astronuclear Laboratory

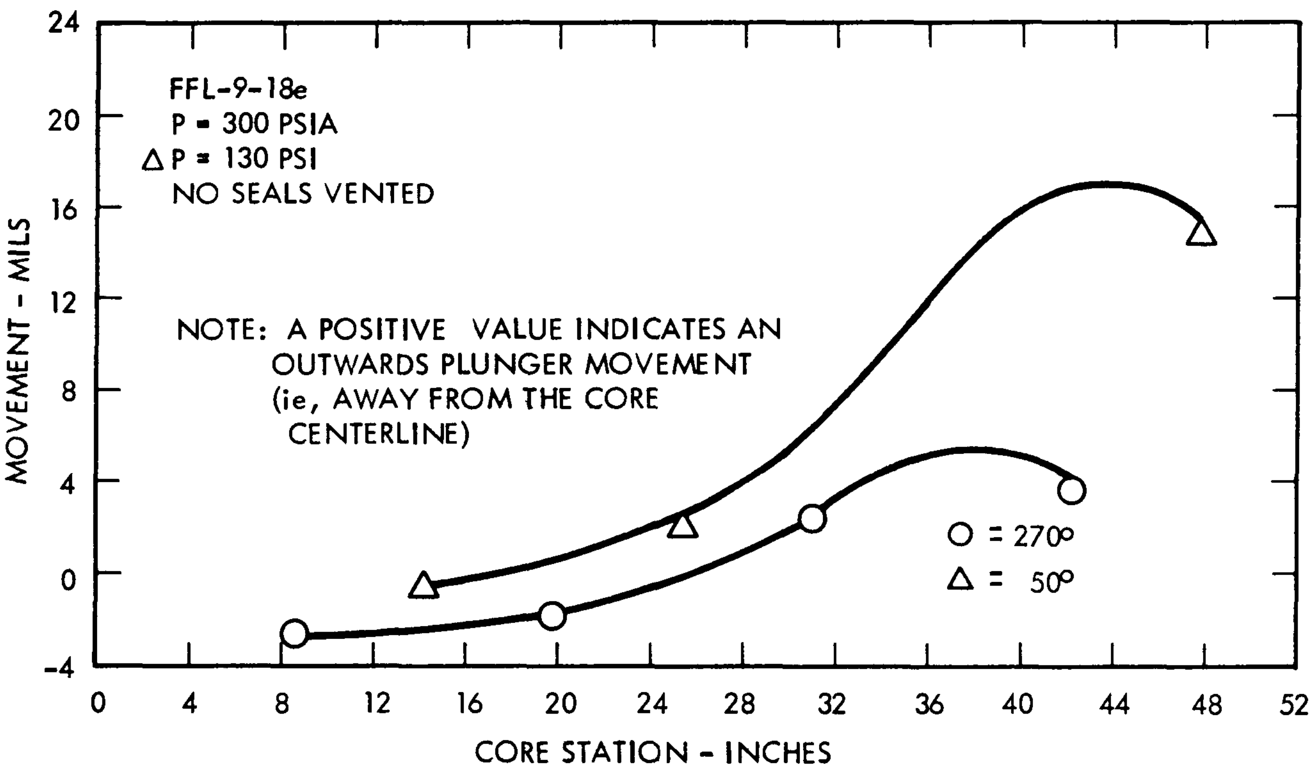


603379-14B

FIGURE 47

APPARENT PLUNGER PIN MOVEMENT - FFL-9-22b

~~CONFIDENTIAL~~
~~RESTRICTED DATA~~

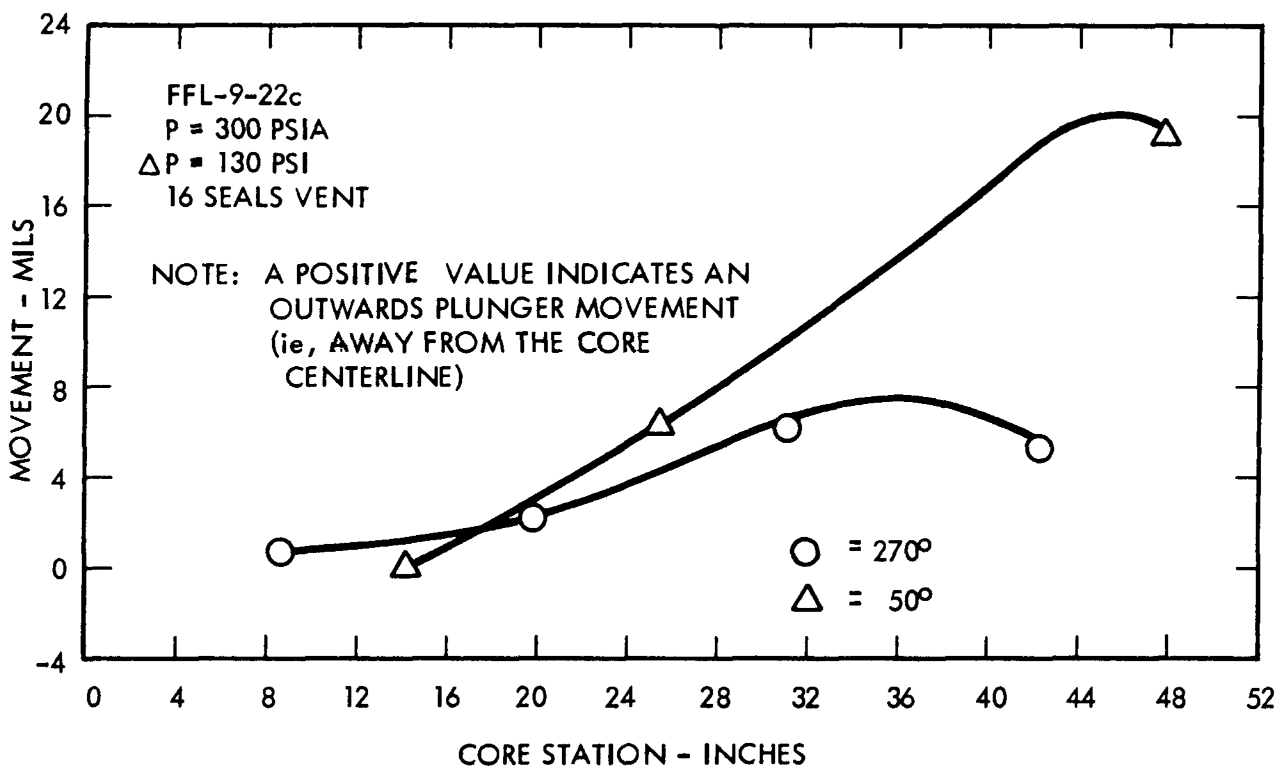


603379-9B

FIGURE 48

APPARENT PLUNGER PIN MOVEMENT - FFL-9-18e

[redacted]



603379-3B

FIGURE 49

APPARENT PLUNGER PIN MOVEMENT - FFL-9-22c

[redacted]